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NOV 80 J P KAHLER, R G CURRY, R A KANDLER

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AIR WEATHER SERVICE

CALCULATING TOXIC CORRIDORS

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Approved For Public Release; Distribution Unlimited

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REVIEW AND APPROVAL STATEMENT

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This technical publication has been reviewed and is approved for publication.

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ERRATA

Make the following corrections to your copy of AWS/TR-80/003, Calculating Toxic Corridors, November 1980.

Page	Correction
vii	Line 9, The Time Factor. Change page number to 3.
vii	Line 15, Change Chapter 5 METHOD 3: UNIVERSAL NOMOGRAM to Chapter 6 - METHOD 3: UNIVERSAL NOMOGRAM
vii	Line 26, Appendix F. Insert "II" after TITAN.
7	STEP 4, line 2. Change "go the" to "go to"
9	Third box down on left. Change "6775" to "6076"
44	Third box down on left. Change "6775" to "6076"
44	Sixth block down in center. Change "FIG. 1" to "FIG. 3"
45	Line 32. Change "Perch loroethylene" to one word "Perchloroethylene"
46	Insert "and" before "Source Strength" in the caption.
51	Third box down on left. Change "6775" to "6076"
51	Fifth block down on right. Change "FIG. 5" to "FIG. 6"
55	First paragraph, line 8. Change "Method 1" to "Method 4"
60	Third box down on left. Change "6775" to "6076"
74	Opposite Chlorine Pentafluoride under "VAPOR PRESSURE in Hq" change 1_9.599 to 119.599

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Toxic Corridors	Missile Propellants	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Method for defining evacuation areas for accidental spills of toxic chemicals are presented. These spills can present serious health hazards to people exposed to excessive vapor concentrations downwind of the accident. An empirical diffusion equation is used to calculate the downwind hazard distance. The width of the toxic corridor, specified in angular degrees centered along the mean wind direction, is based upon the variability of the wind direction. Flexibility in estimating toxic corridor evacuation areas is allowed through a choice of four different methods involving the use of tables, nomograms, and

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a programmable calculator. Appendices present worksheets, example problems, procedures for determining meteorological inputs, a procedure for determining evaporative source strength, and other items.

PREFACE

The Air Weather Service (AWS) is tasked by AFR 355-1, 14 May 1979, (para 2-12g) to provide diffusion predictions for toxic chemicals released to the atmosphere. This technical report presents several forms of a simple technique for use by AWS detachment forecasters for determining toxic corridors in the event of an accidental spill or release to the atmosphere of a toxic chemical. These techniques are largely based upon AWS Pamphlet 105-57, "Calculation of Toxic Corridors," (which has been rescinded), AWSTR 176, "Diffusion Forecasting for TITAN II Operations," and AFGL Report, "The Ocean Breeze and Dry Gulch Diffusion Program, Volume II." Additional information can be found in AWSTR 214, "Guide to Local Diffusion of Air Pollutants". These references and others pertaining to the Ocean Breeze and Dry Gulch programs and toxic corridor forecasting are listed in the references.

The basic technique of using toxic corridor tables calculated from the Ocean Breeze and Dry Gulch equation has been in use for nearly two decades by weather units supporting TITAN missile operations. During that period slight modifications and refinements to the procedures have been made but the basis for the technique has remained the same. This technical report continues the use of the above equation to determine toxic corridor lengths and contains additional, alternative approaches for arriving at the same answer. This additional flexibility should allow AWS forecasters the opportunity to select the means of making these calculations that is best suited to their particular situation.

The authors of this report wish to acknowledge the contributions made by several individuals in their review of this technical report. Maj William Normington from the USAF Occupational and Environmental Health Laboratory provided a general technical review. Col Victor C. Furtado, Chief of Bioenvironmental Engineering, Aerospace Consultants Division, Office of the Surgeon General, reviewed several sections of the report and confirmed many of the exposure limits listed in the table of chemical factors. Air Weather Service Mobilization Augmentee Lt Col James Dicke provided an extremely detailed and comprehensive editorial and technical review of the entire report. The authors sincerely appreciate the contributions provided by all of the above individuals.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

Chapter 1

INTRODUCTION

The duty forecaster answers the telephone and receives the following message: "A tank truck carrying liquid chlorine jack-knifed near the main gate. The tank ruptured and is spewing chlorine all over. A large chlorine gas cloud is moving across the base toward the housing area. We need to know what areas should be evacuated."

At this point, the duty forecaster must realize that a toxic corridor is required and must know how to prepare one. A large number of lives may depend upon this forecaster's response.

The potential for this type of accident exists virtually everywhere. It is not necessary that toxic chemicals routinely be moved, used, or stored on your installation. Any installation located near highways or railroads is a potential candidate for a toxic spill from trucks or trains that transport chemicals along these routes. The call for a toxic corridor forecast will likely come when least expected. Will you be ready to respond rapidly and accurately to such a request?

This report outlines specific procedures to swiftly provide toxic corridor information based upon atmospheric diffusion considerations at the time of an emergency. Several different approaches to calculating toxic corridors are presented. These techniques are based upon the observed and forecast wind, temperature difference between 54 feet and 6 feet (delta-T), and information pertaining to the toxic chemical that has been spilled or released to the atmosphere.

Toxic corridors represent emergency evacuation areas downwind of accidental spills of toxic chemicals. These spills can occur anywhere toxic chemicals are handled or transported such as missile sites, chemical storage areas, or along rail, water, and highway shipping routes. Specifically, a toxic corridor is the area within which the risk to people from excessive vapor concentrations exceeds an acceptable level.

Assuming correct input parameters are used, the toxic corridor calculated using the techniques presented in this report will result in an area within which the probability is 90 percent that concentrations above a specified limit will be contained. In many cases, this specified concentration will be an estimated or established Short-Term Public Emergency Limit (SPEL). The National Academy of Sciences Committee of Toxicology (1979) has established exposure limits for a large number of toxic chemcials.

The boundary of a toxic corridor does not represent a clearly defined line where one side represents a hazard and the other side complete safety. Remember, a 10-percent probability exists that an exposure limit can be exceeded outside of the specified corridor.

A toxic corridor calculated using this report represents a quick response approach to an emergency situation that should minimize the risks while not requiring excessive areas to be evacuated. The calculation procedures are simple, rapid, and suited to emergency situations.

Chapter 2

SUGGESTIONS AND CAUTIONS IN CALCULATING TOXIC CORRIDORS

Lack of Tables for a Particular Toxic Chemical

Occasionally, a corridor table not included in this report may be required for use with Method 1. If assistance in obtaining this information is required, submit a request through channels to Headquarters Air Weather Service, DCS Aerospace Sciences.

If you wish to pursue the problem yourself, ask your local Bioenvironmental Engineer (BEE) for help. First determine the appropriate exposure limit. Normally, this will be the 30-minute Short-Term Public Emergency Limit (SPEL). Unfortunately, SPEL's have not been established for many toxic chemicals. A gram molecular weight for the toxic chemical is also needed. If a SPEL has not been established, work out an acceptable exposure limit for the toxic chemical with the BEE. It is not the intent of this report to provide a procedure for determining an exposure limit. Once an exposure limit and a gram molecular weight has been established, Method 2, 3, or 4 can be used to determine a toxic corridor. If you prefer, produce a toxic corridor table and use Method 1. Plan ahead for any credible emergency. Obviously, it would be impractical to begin developing new tables during an emergency.

Wind Direction Variability (R)

Instructions for determining wind direction variability, which is directly related to the lateral diffusion of the toxic chemical, are provided in the steps for calculating toxic corridors by each method. At locations where direct readouts of wind direction standard deviations (σ_θ) are available, wind direction variability (R) is approximately equal to (16/3) σ_θ. This makes the corridor width (W), which is 1.5R, equal to 8 σ_θ, i.e., $(3/2)\cdot(16/3)\ \sigma_\theta = 8\ \sigma_\theta$ (Taylor, 1963).

Types of Corridors

Organizations that operate TITAN II sites are prime users of toxic corridor forecasts by Air Weather Service units. Strategic Air Command (SAC) Bioenvironmental personnel have worked closely with the 3rd Weather Wing Staff in carefully planning the use of these toxic corridor diffusion forecasts. SACR 355-5 defines different types of corridors based upon operational requirements. The definitions below are examples of the ways these diffusion forecasts are used.

a. A Propellant Emission Corridor is established when planned emission of propellants are to occur, e.g., tank venting or purging operations. The exposure limit used for calculating this type of toxic corridor is the 10-minute Short-Term Public Limit (STPL). Since this is a scheduled occurrence, a decision must be made as to whether the planned task can be performed without unacceptable exposures to the general public.

b. A Potential Hazard Corridor is established when no release of propellants to the environment is planned, but propellants will be in a nonstatic, e.g., propellant transfer, mode. The 10-, 30-, and 60-minute Short-Term Public Emergency Limits (SPEL) are used as exposure limits for calculating these toxic corridors.

c. An Operational Hazard Corridor is established and periodically updated if an actual propellant spill or mishap occurs. Immediate steps must be taken to evacuate unprotected personnel from the established potential hazard corridor until the exact size of the operational hazard corridor is established. The 10-, 30-, and 60-minute Short-Term Public Emergency Limits (SPEL) are used as the exposure limits for calculating these toxic corridors. Note: The primary difference between potential and operational hazard corridors is that the former is calculated in anticipation of a potential spill and the latter after a spill has occurred.

The Time Factor

A major consideration during emergencies created by accidental spills of toxic chemcials is the reaction time required to evacuate people from the hazardous area. Plans for emergency evacuation should be established so that evacuation is started without delay. Therefore, evacuation might have started before a toxic corridor calculation can be made. The following steps outline one possible sequence of events.

a. As soon as a toxic spill occurs, the Disaster Response Force (DRF) clears an area of a predetermined radius around the spill site. Base Weather is notified and provides wind information (direction and speed) representative of the spill location at that time. In some instances, e.g., at TITAN missile sites, wind and temperature difference information normally will be provided to Base Weather from the site of the spill.

b. The DRF begins evacuating areas downwind of the site staying as far ahead of the leading edge of the toxic cloud as possible. The leading edge, even if visible, may not be the toxic edge of the cloud.

c. Base Weather completes toxic corridor forecast calculations and relays the information to the DRF which completes the evacuation of the toxic corridor.

d. Base Weather continues close monitoring of weather conditions, updates the toxic corridor forecast as necessary, and relays any significant changes to the DRF.

Potential Sources of Error

Several potential sources of error might contribute to an erroneous estimate of toxic corridors. Errors can occur when measuring or estimating the temperature difference (delta-T) and when estimating source strength and trends in meteorological parameters. Other errors may stem from peculiarities of the toxic chemical, terrain effects that alter the wind and diffusion characteristics of the atmosphere, and the horizontal homogeneity assumption. Each of these potential error sources are briefly discussed in this section.

Toxic corridor lengths are extremely sensitive to the delta-T values used in making the calculations. For example, a $1^{o}F$ error in delta-T can result in an error as large as 40 percent in the corridor length. Appendix D provides additional information on this error.

Source strength errors are not as critical as delta-T errors; however, source strength is much more difficult to estimate than delta-T. Corridor lengths are approximately proportional to the square root of the source strength. Appendix C contains information on this error.

Past experience and research have shown that gases such as chlorine which are considerably denser than air do not initially disperse in the same way as gases with densities nearly the same as air. When a large amount of dense gas is released at one time, the spill will form a density front and initially spread in all directions at once. This can result in a situation where the upwind edge of a highly concentrated gas cloud travels against the wind and spreads upwind of the spill site. Whether or not the upwind edge of a dense gas cloud travels against the wind depends upon whether or not the velocity of the density front is greater than the wind velocity. The density front also causes the initial lateral spread of the cloud to be larger than normal. Vertical spread of the gas will be initially much less than normal and the gas cloud will tend to hug the ground, especially if there is no added buoyancy due to heating/combustion. The cloud will flow downhill and tend to follow terrain features such as rivers and valleys and, again, may somewhat "ignore" the direction of the wind. After the gas cloud has traveled a sufficient distance and entrained enough air, its density will be similar to that of air allowing it to diffuse in a more classical Gaussian manner (van Ulden, 1974 and Eidsvik, 1978).

The dense gas effect may cause toxic corridors to be longer than calculated, particularly when the delta-T is negative. Preliminary results of comparisons between a dense gas model and the Ocean Breeze and Dry Gulch model indicate that the differences between calculated corridor lengths tend to disappear under extremely stable (large, positive delta-T) atmospheric conditions. Research into the dense gas problem is on-going and should result in more definitive guidance in the future.

Terrain and surface roughness elements can affect not only the atmospheric dispersion but also the wind direction and speed. The procedure for estimating delta-T (Table B-1) calls for adding $-1^{o}F$ to the estimated value if the toxic spill occurs in rough terrain. Atmospheric diffusion can be enhanced by the increase in turbulence caused by flow over rough terrain. Large buildings and terrain features such as hills and bodies of water can alter wind direction downwind of a spill. Since wind speed is used in terms of several categories in Table B-1 and does not appear in the Ocean Breeze and Dry Gulch equation, a precise value is not critical; however, the correct category is as important as the temperature difference (delta-T) value. These effects must be considered when defining a toxic corridor.

Toxic corridor forecasts should be updated when wind direction changes occur or are forecast to occur. These changes may be due to several causes including 1) passage of a front or trough, 2) the onset of drainage winds in mountainous regions and, 3) shore line wind direction reversals over coastal regions.

There are several reasons why the temperature difference values in Table B-1 should be modified when there is a toxic chemical release in or very near forested areas. Empirical data show that chemical plumes/clouds under forest canopies tend to expand to much larger volumes, at shorter travel distances, than those on generally open, relatively level terrain. Field data also show that wind speeds under canopies are much lower than wind speeds measured on open, level terrain at any given time. Thus, chemical plumes/clouds travel much farther in a given time over open, level terrains than they do in forests under any given weather situation. Although Johnson (1980) contains an extensive table of corrections applicable to a computer-based model developed for the Department of Defense (DOD), directly applying the corrections to the methods in this report is neither possible nor warranted. Rather, if a toxic chemical release occurs in a forest or is forecast to flow into a forest immediately after release, the forecaster should use the next lower wind speed category to that normally applicable if the out-of-canopy wind speed exceeds 3 knots. Then, add (-1) to the number in Table B-1 before entering the appropriate toxic corridor length table. This approximation does not justify using a number more negative than (-4) in calculating toxic corridor length, even if the spill is in rough terrain.

Any diffusion estimation technique that uses one set of meteorological parameters as inputs assumes the conditions described by these parameters are horizontally homogeneous; i.e., they do not change in the horizontal. Over relatively flat and uniform terrain this assumption is valid; however, the forecaster must insure that factors affecting the representativeness of the input data for a toxic corridor forecast have been considered.

The important aspect of considering potential sources of error is to know what they are and to watch for them in your particular situation. Remember that the procedures in this report are intended for emergency situations and must, therefore, be kept as simple as possible. Time does not permit, and sufficient meteorological data will not usually be available to run a fine-grid numerical model. Thus, a quick and simple technique, tempered by forecaster judgement, must be used to produce a best estimate of the hazard area.

Chapter 3

CALCULATING TOXIC CORRIDORS

The following chapters contain step-by-step instructions for calculating toxic corridors using any of four methods. Since the results of toxic corridor calculations are virtually the same, regardless of the method used, the method of choice will likely depend on frequency of forecast request, experience of the forecaster in making this forecast, availability of a toxic corridor length table for the released chemical, and availability of a TI-59 programmable calculator. Method 1 will most likely be used if there is a toxic corridor length table for the chemical; Method 2 if there is no table. Method 3 requires more independent data and would be applicable for unusual combinations of toxic chemicals and exposure limits. Method 4 may be preferred by those skilled in using programmable calculators where specific situations can be handled by executing the general equations in this report. The separate sections for each method are self-contained except that the suggested worksheet is in Appendix A and procedures for determining meteorological elements are in Appendix B. In all four methods, the technique to determine the corridor is a quick, objective, persistence forecast. The forecaster should be alert to factors that could change the wind direction/variability and speed. Atmospheric stability, as reflected by delta-T, changes from hour to hour during the day. Calculations should be repeated if major variables such as source strength, delta-T, wind speed, wind direction, or wind variability change.

Further Consideration

The toxic area should be evacuated until the DRF determines that the hazard no longer exists. Disaster teams should approach from the upwind side and wear appropriate protective equipment. It is important to realize that the toxic material may diffuse in all directions in light and variable winds. Except for denser than air concentrated gas clouds discussed in the previous section of this report, the material will move downwind at approximately the speed of the wind. For instantaneous releases, a toxic cloud will form, while short-term releases will create a short plume. Once the source is terminated, the end of the plume will diffuse as it moves downwind. Therefore, the toxic corridor is active until the material has time to diffuse to an acceptable level.

Be prepared to transfer the worksheet sketch of the corridor to an appropriate map. Insure that the corridor is drawn to map scale. General requirements regarding maps and plotting requirements are contained in AFR 355-1. The local disaster preparedness plan should specify the scale and map to use. Table 1 provides conversion factors that can be used to convert feet to other length units. These factors may help you in making scale drawings.

Table 1. Length Conversion Factors.

Convert From	To	Conversion Factor
Feet	Meters	3.048×10^{-1}
Feet	Kilometers	3.048×10^{-4}
Feet	Statute Miles	1.894×10^{-4}
Feet	Nautical Miles	1.646×10^{-4}

Chapter 4

METHOD 1: TOXIC CORRIDOR LENGTH TABLES

The steps to determine the dimensions of a toxic corridor using this method are presented below. Where applicable, preferred and alternate approaches are given. Toxic corridor length Tables 2 through 32 are required. Two copies of a suggested worksheet are provided in Appendix A, one with sample corridor calculations (Figure A-1) and one blank copy (Figure A-2). A flow chart fot using Method 1 is depicted in Figure 1.

a. STEP 1: Determine source strength (lb/min).

(1) Preferred. Obtain a source strength from the disaster response force (DRF). NOTE: Although weather personnel are not responsible for determining source strength, a toxic corridor length calculation cannot be made without it. Appendix C provides an equation for calculating evaporative source stengths based on the surface area covered by the toxic chemical spill. Use this appendix to assist the agency responsible for estimating source strengths.

(2) Alternate. For small amounts of liquid or gas (less than 2000 lb), assume the worst case which is total release of the material in one minute. For large amounts of gas, assume total release over five minutes. For large amounts of liquid, assume a source strength of 2000 lb per minute.

(3) Alternate. For releases of a large amount of material where a source strength cannot be determined from the above procedures, go to alternate procedure in Step 3.

b. STEP 2: Determine temperature difference (delta-T (^{o}F)).

(1) Preferred. Use the mean delta-T based on at least a 10-minute record from a 54-6 foot delta-T instrument. (Available at TITAN II missile sites. Refer to Appendix B, Figure B-1.) NOTE: 54-6 foot delta-T measurements can be made by using a sling psychrometer at the 54- and 6-foot levels of a radar tower.

(2) Alternate. Use mean surface wind speed category, solar elevation angle, and sky condition to obtain an estimated temperature difference from Table B-1, Appendix B. Refer to the notes in this table concerning rough terrain and forested regions prior to estimating the temperature difference.

c. STEP 3: Determine toxic corridor length (TCL) in feet.

(1) Preferred. Turn to the appropriate toxic chemical corridor length table. Read across from the source strength determined in Step 1 and down from the temperature difference determined in Step 2. The intersected value is the toxic corridor length.

(2) Alternate. For releases of a large amount of material where no source strength is available, use the distance the wind would carry the material in one hour. This is an interim forecast which must be updated when particulars are known.

d. STEP 4: Determine mean wind direction and wind direction variability, R (degrees of azimuth). If the surface wind is equal to or less than 3 knots, go the Step 6.

(1) Preferred. Use the 10-minute recorded wind direction trace and eliminate the two furthest direction fluctuations on each side of the mean. Variability, R, is the difference in degrees between the third largest fluctuation on each side of the mean direction.

(2) Alternate. Note the wind fluctuations indicated by an anemometer dial over a 2-minute period. Variability, R, is the difference in degrees between the largest fluctuation on each side of the mean direction.

(3) Approximate. If wind direction fluctuation information is unavailable, assume R is 60° when the wind speed is between 4 and 10 knots; assume R is 30° when the wind speed is greater than 10 knots.

e. STEP 5: Determine corridor width (W) in degrees by multiplying the value obtained for R in Step 4 by 1.5.

f. STEP 6: Plot the toxic corridor.

(1) Wind speed greater than 3 knots. Draw the corridor center line from the source to the point on the wind direction circle corresponding to the direction the mean wind is blowing towards (i.e., 180 degrees from the recorded mean wind direction), as determined in Step 4. Place W/2, calculated in Step 5, on each side of the center line. Draw the lines which define each side of the corridor. See example worksheet, Figure A-1 in Appendix A.

(2) Wind speed equal to or less than 3 knots. The corridor is a circle of radius equal to the corridor length determined in Step 3.

g. STEP 7: Trend forecast. If significant changes in wind direction are expected within the next hour or two, include this information in the briefing. A change in direction that would affect evacuation is significant. Based on continued, close monitoring of weather conditions, relay any significant changes in the toxic corridor forecast to the DRF. Consider changes in winds that have occurred between the time of the spill and the time of the forecast. These changes could alter the shape and size of the toxic corridor.

TOXIC CORRIDOR CALCULATIONS
USING METHOD 1

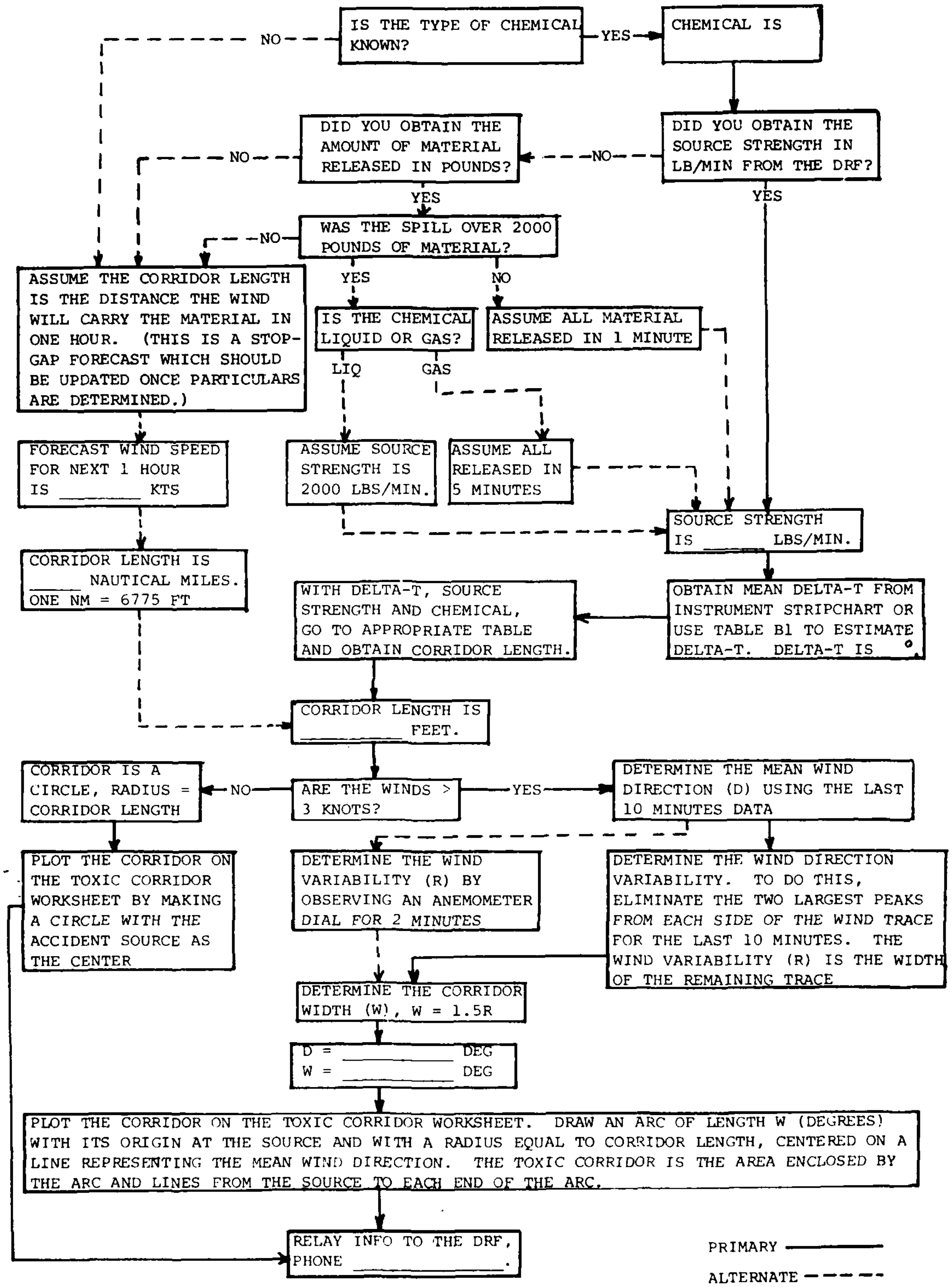


Figure 1. Flow Chart for Method 1. (NOTE: Lt Alan Shaffer of Det 7, 24WS, Mather AFB, CA developed the original version of this flow chart. Except for a few minor changes by 5WW/DN and the authors of this TN, the flow chart remains as originally developed.)

TABLE 2. AEROZINE 50 TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 20 PPM (30-MINUTE SPEL).

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	103.	152.	213.	287.	375.	477.	595.	728.	879.	1046.	1232.	1436.
5.0	235.	347.	487.	656.	856.	1090.	1353.	1663.	2006.	2389.	2812.	3279.
10.0	336.	496.	695.	936.	1222.	1555.	1938.	2373.	2863.	3409.	4013.	4679.
15.0	413.	610.	856.	1153.	1505.	1915.	2380.	2922.	3525.	4197.	4941.	5760.
20.0	479.	707.	992.	1336.	1744.	2219.	2760.	3387.	4085.	4864.	5727.	6676.
30.0	590.	871.	1221.	1645.	2147.	2733.	3405.	4170.	5030.	5989.	7051.	8220.
40.0	683.	1009.	1415.	1906.	2488.	3167.	3947.	4833.	5830.	6941.	8172.	9527.
50.0	766.	1132.	1587.	2137.	2790.	3551.	4426.	5419.	6537.	7783.	9164.	10683.
75.0	943.	1393.	1953.	2632.	3435.	4372.	5449.	6672.	8048.	9583.	11282.	13153.
150.0	1346.	1988.	2788.	3755.	4902.	6239.	7776.	9521.	11484.	13675.	16100.	18769.
200.0	1560.	2305.	3231.	4352.	5682.	7231.	9012.	11035.	13311.	15849.	18661.	21754.
300.0	1921.	2837.	3978.	5359.	6996.	8903.	11096.	13587.	16389.	19514.	22975.	26784.
400.0	2227.	3289.	4610.	6211.	8108.	10319.	12861.	15747.	18995.	22617.	26629.	31043.
500.0	2497.	3688.	5170.	6964.	9092.	11571.	14420.	17657.	21298.	25360.	29859.	34808.
750.0	3074.	4540.	6365.	8575.	11194.	14246.	17754.	21740.	26223.	31224.	36762.	42856.
1000.0	3563.	5262.	7377.	9938.	12974.	16512.	20578.	25197.	30393.	36190.	42609.	49672.
2000.0	5084.	7509.	10527.	14182.	18514.	23563.	29365.	35957.	43372.	51643.	60803.	70882.
3000.0	6260.	9246.	12961.	17461.	22795.	29011.	36155.	44270.	53400.	63584.	74862.	87271.
4000.0	7255.	10716.	15023.	20238.	26420.	33624.	41904.	51311.	61892.	73695.	86767.	101150.
5000.0	8135.	12016.	16845.	22692.	29624.	37702.	46987.	57534.	69398.	82633.	97290.	113418.

TABLE 3. ANHYDROUS AMMONIA TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 75 PPM (30-MINUTE SPELL).

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	72.	107.	150.	202.	263.	335.	418.	511.	617.	734.	865.	1008.
5.0	165.	244.	342.	461.	601.	705.	954.	1168.	1408.	1677.	1974.	2302.
10.0	236.	348.	488.	657.	858.	1092.	1361.	1666.	2010.	2393.	2817.	3284.
15.0	290.	428.	601.	809.	1056.	1344.	1675.	2051.	2474.	2946.	3465.	4044.
20.0	336.	497.	696.	938.	1224.	1558.	1942.	2378.	2868.	3415.	4020.	4687.
30.0	414.	611.	857.	1155.	1507.	1918.	2391.	2927.	3531.	4204.	4950.	5771.
40.0	480.	709.	993.	1338.	1747.	2223.	2771.	3393.	4092.	4873.	5737.	6688.
50.0	538.	794.	1114.	1500.	1959.	2493.	3107.	3804.	4589.	5464.	6433.	7499.
75.0	662.	978.	1371.	1847.	2412.	3069.	3825.	4684.	5650.	6727.	7921.	9233.
150.0	945.	1396.	1957.	2636.	3442.	4380.	5459.	6684.	8062.	9600.	11303.	13176.
200.0	1095.	1618.	2268.	3056.	3989.	5077.	6327.	7747.	9345.	11127.	13100.	15272.
300.0	1349.	1992.	2793.	3762.	4911.	6250.	7790.	9538.	11505.	13699.	16125.	18803.
400.0	1563.	2309.	3237.	4360.	5692.	7244.	9028.	11055.	13335.	15878.	18694.	21793.
500.0	1753.	2589.	3629.	4889.	6383.	8123.	10123.	12396.	14952.	17804.	20961.	24436.
750.0	2156.	3187.	4468.	6020.	7858.	10001.	12464.	15262.	18409.	21920.	25808.	30086.
1000.0	2501.	3694.	5179.	6977.	9108.	11592.	14446.	17689.	21337.	25406.	29912.	34871.
2000.0	3569.	5272.	7390.	9956.	12997.	16542.	20615.	25242.	30448.	36255.	42685.	49761.
3000.0	4395.	6451.	9099.	12258.	16002.	20366.	25381.	31079.	37488.	44637.	52555.	61266.
4000.0	5093.	7523.	10546.	14207.	18547.	23605.	29418.	36021.	43450.	51736.	60912.	71010.
5000.0	5711.	8435.	11825.	15931.	20797.	26488.	32986.	40390.	48719.	58011.	68300.	79622.

TABLE 4. ANILINE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 20 PPM (1/5 OF 30-MINUTE EEL).

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	60.	88.	123.	166.	217.	270.	344.	421.	508.	605.	713.	831.
5.0	136.	201.	282.	379.	495.	630.	786.	962.	1161.	1382.	1627.	1897.
10.0	194.	287.	402.	542.	707.	900.	1121.	1373.	1656.	1972.	2322.	2707.
15.0	239.	353.	495.	667.	870.	1100.	1331.	1690.	2039.	2428.	2859.	3332.
20.0	277.	409.	574.	773.	1009.	1284.	1600.	1959.	2363.	2814.	3313.	3862.
30.0	341.	504.	706.	951.	1242.	1581.	1970.	2412.	2910.	3465.	4079.	4755.
40.0	395.	584.	819.	1103.	1440.	1832.	2283.	2796.	3372.	4016.	4728.	5512.
50.0	443.	655.	918.	1236.	1614.	2054.	2560.	3135.	3781.	4503.	5301.	6180.
75.0	546.	806.	1130.	1522.	1987.	2529.	3152.	3860.	4656.	5544.	6527.	7609.
150.0	779.	1150.	1613.	2172.	2836.	3609.	4498.	5508.	6644.	7911.	9314.	10858.
200.0	903.	1333.	1869.	2518.	3287.	4184.	5214.	6384.	7701.	9165.	10795.	12585.
300.0	1111.	1642.	2301.	3100.	4047.	5151.	6419.	7860.	9481.	11285.	13292.	15495.
400.0	1288.	1903.	2667.	3593.	4691.	5970.	7440.	9110.	10989.	13084.	15405.	17959.
500.0	1444.	2133.	2991.	4029.	5260.	6694.	8342.	10215.	12322.	14671.	17274.	20137.
750.0	1778.	2627.	3682.	4961.	6476.	8242.	10271.	12577.	15170.	18064.	21268.	24793.
1000.0	2061.	3044.	4268.	5749.	7506.	9552.	11905.	14577.	17583.	20936.	24650.	28736.
2000.0	2941.	4344.	6090.	8204.	10711.	13631.	16988.	20801.	25091.	29876.	35176.	41006.
3000.0	3621.	5349.	7498.	10101.	13187.	16783.	20916.	25611.	30893.	36784.	43309.	50488.
4000.0	4197.	6199.	8691.	11708.	15284.	19452.	24242.	29684.	35805.	42634.	50196.	58517.
5000.0	4706.	6951.	9745.	13128.	17138.	21811.	27182.	33284.	40148.	47805.	56284.	65614.

TABLE 5. BROMINE PENTAFLUORIDE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 0.3 PPM (1/5 OF 30-MINUTE EEL).

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	372.	545.	770.	1037.	1354.	1723.	2148.	2630.	3172.	3777.	4447.	5184.
5.0	845.	1254.	1758.	2368.	3092.	3935.	4904.	6005.	7243.	8624.	10154.	11837.
10.0	1212.	1790.	2509.	3380.	4412.	5615.	6998.	8569.	10336.	12307.	14490.	16892.
15.0	1492.	2203.	3089.	4161.	5432.	6914.	8616.	10550.	12726.	15153.	17840.	20798.
20.0	1729.	2554.	3580.	4823.	6296.	8013.	9986.	12228.	14750.	17563.	20678.	24105.
30.0	2129.	3144.	4408.	5938.	7752.	9866.	12295.	15055.	18160.	21623.	25459.	29679.
40.0	2467.	3644.	5109.	6882.	8985.	11435.	14251.	17449.	21048.	25062.	29507.	34399.
50.0	2767.	4086.	5728.	7717.	10074.	12822.	15979.	19566.	23601.	28102.	33086.	38570.
75.0	3406.	5031.	7053.	9501.	12404.	15786.	19674.	24090.	29057.	34595.	40736.	47489.
150.0	4861.	7179.	10065.	13559.	17700.	22527.	28074.	34376.	41465.	49373.	58131.	67767.
200.0	5634.	8321.	11665.	15715.	20515.	26110.	32539.	39843.	48060.	57225.	67375.	78544.
300.0	6936.	10245.	14362.	19348.	25259.	32147.	40063.	49055.	59172.	70457.	82954.	96704.
400.0	8039.	11874.	16646.	22425.	29275.	37259.	46434.	56857.	68582.	81661.	96145.	112083.
500.0	9015.	13314.	18665.	25145.	32826.	41778.	52065.	63752.	76899.	91565.	107806.	125677.
750.0	11099.	16393.	22981.	30959.	40416.	51437.	64104.	78493.	94680.	112737.	132733.	154735.
1000.0	12864.	19000.	26636.	35882.	46843.	59617.	74298.	90976.	109737.	130665.	153841.	179343.
2000.0	18357.	27113.	38010.	51205.	66846.	85075.	106024.	129823.	156596.	186461.	219533.	255924.
3000.0	22601.	33382.	46798.	63044.	82302.	104745.	130539.	159841.	192803.	229573.	270293.	315098.
4000.0	26196.	38690.	54240.	73070.	95390.	121403.	151298.	185260.	223464.	266082.	313277.	365208.
5000.0	29373.	43383.	60819.	81932.	106959.	136127.	169648.	207729.	250567.	298353.	351272.	409501.

TABLE 6. CARBON DISULFIDE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 20 PPM (1/5 OF 30-MINUTE EEL).

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	66.	98.	137.	184.	241.	306.	382.	467.	564.	671.	790.	921.
5.0	151.	223.	312.	421.	549.	699.	871.	1067.	1287.	1532.	1804.	2103.
10.0	215.	318.	446.	600.	784.	998.	1243.	1522.	1836.	2187.	2574.	3001.
15.0	265.	391.	549.	739.	965.	1228.	1531.	1874.	2261.	2692.	3170.	3695.
20.0	307.	454.	636.	857.	1119.	1424.	1774.	2173.	2621.	3120.	3674.	4283.
30.0	378.	555.	783.	1055.	1377.	1753.	2185.	2675.	3226.	3842.	4523.	5273.
40.0	438.	647.	908.	1223.	1596.	2032.	2532.	3100.	3740.	4453.	5243.	6112.
50.0	492.	726.	1018.	1371.	1790.	2278.	2839.	3476.	4193.	4993.	5878.	6853.
75.0	605.	894.	1253.	1688.	2204.	2805.	3495.	4280.	5163.	6147.	7236.	8437.
150.0	864.	1276.	1788.	2409.	3145.	4002.	4988.	6108.	7367.	8772.	10328.	12040.
200.0	1001.	1478.	2073.	2792.	3645.	4639.	5781.	7079.	8539.	10167.	11971.	13955.
300.0	1232.	1820.	2552.	3438.	4488.	5712.	7118.	8716.	10513.	12518.	14738.	17182.
400.0	1428.	2110.	2958.	3984.	5201.	6620.	8250.	10102.	12185.	14509.	17082.	19914.
500.0	1602.	2366.	3316.	4468.	5832.	7423.	9250.	11327.	13663.	16268.	19154.	22329.
750.0	1972.	2913.	4083.	5501.	7181.	9139.	11389.	13946.	16822.	20030.	23583.	27492.
1000.0	2286.	3376.	4732.	6375.	8323.	10592.	13201.	16164.	19497.	23215.	27333.	31864.
2000.0	3261.	4817.	6753.	9098.	11877.	15115.	18837.	23066.	27823.	33129.	39005.	45470.
3000.0	4016.	5931.	8315.	11201.	14623.	18610.	23193.	28399.	34256.	40789.	48023.	55984.
4000.0	4654.	6874.	9637.	12982.	16948.	21570.	26881.	32915.	39703.	47275.	55660.	64887.
5000.0	5219.	7708.	10806.	14557.	19004.	24186.	30141.	36907.	44518.	53009.	62411.	72756.

TABLE 7. CARBON MONOXIDE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 100 PPM (30-MINUTE SPEL).

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	48.	71.	100.	135.	176.	224.	279.	342.	412.	491.	578.	674.
5.0	110.	163.	228.	308.	402.	511.	637.	780.	941.	1121.	1320.	1538.
10.0	157.	233.	326.	439.	573.	730.	910.	1114.	1343.	1600.	1883.	2195.
15.0	194.	286.	401.	541.	706.	899.	1120.	1371.	1654.	1969.	2319.	2703.
20.0	225.	332.	465.	627.	818.	1041.	1298.	1589.	1917.	2283.	2687.	3133.
30.0	277.	409.	573.	772.	1007.	1282.	1598.	1957.	2360.	2810.	3309.	3857.
40.0	321.	474.	664.	894.	1168.	1486.	1852.	2268.	2736.	3257.	3835.	4471.
50.0	360.	531.	745.	1003.	1309.	1666.	2077.	2543.	3067.	3652.	4300.	5013.
75.0	443.	654.	917.	1235.	1612.	2052.	2557.	3131.	3776.	4497.	5294.	6172.
150.0	632.	933.	1308.	1762.	2300.	2928.	3649.	4468.	5389.	6417.	7555.	8807.
200.0	732.	1081.	1516.	2042.	2665.	3393.	4229.	5178.	6245.	7437.	8756.	10208.
300.0	901.	1331.	1867.	2515.	3283.	4178.	5207.	6376.	7690.	9157.	10781.	12568.
400.0	1045.	1543.	2163.	2915.	3805.	4842.	6035.	7389.	8913.	10613.	12496.	14567.
500.0	1172.	1730.	2426.	3268.	4266.	5430.	6767.	8286.	9994.	11900.	14011.	16334.
750.0	1442.	2131.	2987.	4024.	5253.	6685.	8331.	10201.	12305.	14652.	17251.	20110.
1000.0	1672.	2469.	3462.	4663.	6088.	7748.	9656.	11824.	14262.	16982.	19994.	23308.
2000.0	2386.	3524.	4940.	6655.	8688.	11057.	13780.	16873.	20352.	24234.	28532.	33261.
3000.0	2937.	4338.	6082.	8194.	10696.	13613.	16966.	20774.	25058.	29837.	35129.	40952.
4000.0	3405.	5028.	7049.	9497.	12397.	15778.	19664.	24077.	29043.	34582.	40715.	47465.
5000.0	3817.	5638.	7904.	10648.	13901.	17692.	22048.	26998.	32565.	38776.	45653.	53221.

TABLE 8. CHLORINE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 2 PPM (30-MINUTE SPEL).

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	223.	330.	462.	623.	813.	1035.	1290.	1579.	1905.	2268.	2670.	3113.
5.0	510.	753.	1056.	1422.	1857.	2363.	2945.	3606.	4349.	5179.	6097.	7108.
10.0	728.	1075.	1506.	2029.	2649.	3372.	4202.	5145.	6206.	7390.	8701.	10143.
15.0	896.	1323.	1855.	2499.	3262.	4151.	5174.	6335.	7641.	9099.	10712.	12488.
20.0	1038.	1533.	2150.	2896.	3781.	4811.	5996.	7342.	8856.	10546.	12416.	14474.
30.0	1278.	1888.	2647.	3566.	4655.	5924.	7383.	9040.	10904.	12984.	15287.	17821.
40.0	1482.	2188.	3068.	4133.	5395.	6866.	8557.	10478.	12638.	15049.	17718.	20655.
50.0	1661.	2454.	3440.	4634.	6049.	7699.	9595.	11748.	14171.	16874.	19867.	23160.
75.0	2045.	3021.	4235.	5705.	7448.	9479.	11813.	14465.	17448.	20775.	24460.	28515.
150.0	2919.	4311.	6043.	8141.	10628.	13527.	16857.	20641.	24898.	29647.	34905.	40691.
200.0	3383.	4996.	7004.	9436.	12318.	15678.	19538.	23924.	28858.	34361.	40456.	47162.
300.0	4165.	6152.	8624.	11618.	15167.	19303.	24056.	29456.	35530.	42306.	49810.	58067.
400.0	4827.	7130.	9995.	13465.	17579.	22372.	27881.	34140.	41180.	49034.	57731.	67301.
500.0	5413.	7995.	11208.	15098.	19711.	25086.	31263.	38280.	46175.	54981.	64733.	75463.
750.0	6664.	9843.	13799.	18590.	24268.	30886.	38491.	47132.	56851.	67693.	79700.	92912.
1000.0	7724.	11408.	15994.	21546.	28127.	35797.	44613.	54627.	65892.	78458.	92375.	107687.
2000.0	11022.	16280.	22823.	30746.	40138.	51083.	63663.	77953.	94029.	111961.	131820.	153671.
3000.0	13571.	20044.	28100.	37855.	49419.	62895.	78383.	95977.	115770.	137849.	162299.	189203.
4000.0	15729.	23232.	32569.	43875.	57278.	72897.	90348.	111240.	134180.	159770.	188109.	219291.
5000.0	17637.	26049.	36519.	49197.	64224.	81738.	101866.	124732.	150454.	179148.	210923.	245887.

TABLE 9. CHLORINE PENTAFLUORIDE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 0.3 PPM (1/5 OF 30-MINUTE EEL).

DELTA-T (DEG F)

SS LB/MIN	-4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	432.	638.	855.	1206.	1574.	2003.	2496.	3057.	3687.	4390.	5165.	6026.
5.0	987.	1458.	2043.	2753.	3594.	4574.	5700.	6980.	8419.	10024.	11863.	13759.
10.0	1408.	2080.	2916.	3928.	5128.	6527.	8134.	9960.	12014.	14305.	16842.	19634.
15.0	1734.	2561.	3590.	4837.	6314.	8036.	10015.	12263.	14792.	17613.	20737.	24174.
20.0	2010.	2968.	4161.	5606.	7318.	9314.	11607.	14213.	17144.	20414.	24034.	28018.
30.0	2474.	3655.	5123.	6902.	9010.	11467.	14291.	17499.	21108.	25134.	29592.	34497.
40.0	2868.	4236.	5938.	8000.	10443.	13291.	16564.	20282.	24465.	29130.	34297.	39983.
50.0	3216.	4750.	6658.	8970.	11710.	14903.	18573.	22742.	27432.	32663.	38457.	44832.
75.0	3959.	5848.	8198.	11044.	14417.	18349.	22867.	28000.	33775.	40216.	47349.	55198.
150.0	5650.	8345.	11699.	15760.	20574.	26184.	32632.	39957.	48197.	57389.	67568.	78768.
200.0	6548.	9672.	13559.	18266.	23846.	30348.	37821.	46311.	55861.	66515.	78313.	91294.
300.0	8062.	11908.	16694.	22489.	29359.	37365.	46566.	57019.	68778.	81894.	96420.	112403.
400.0	9345.	13802.	19349.	26066.	34028.	43307.	53972.	66087.	79715.	94918.	111753.	130278.
500.0	10478.	15476.	21695.	29227.	38155.	48560.	60517.	74102.	89383.	106430.	125307.	146079.
750.0	12901.	19054.	26712.	35985.	46977.	59787.	74510.	91235.	110050.	131038.	154280.	179855.
1000.0	14952.	22084.	30960.	41707.	54448.	69295.	86359.	105744.	127551.	151877.	178815.	208456.
2000.0	21337.	31514.	44180.	59517.	77698.	98885.	123236.	150899.	182017.	216730.	255172.	297470.
3000.0	26270.	38801.	54395.	73279.	95663.	121749.	151730.	185789.	224103.	266842.	314171.	366250.
4000.0	30448.	44971.	63045.	84932.	110876.	141111.	175859.	215334.	259741.	309277.	364133.	424494.
5000.0	34141.	50425.	70692.	95233.	124323.	158225.	197138.	241451.	291243.	346787.	408256.	475978.

TABLE 10. CHLORINE TRIFLUORIDE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 0.6 PPM (1/5 OF 30-MINUTE EEL).

QS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	361.	534.	748.	1008.	1316.	1675.	2087.	2556.	3083.	3671.	4322.	5038.
5.0	825.	1219.	1709.	2302.	3005.	3824.	4766.	5836.	7039.	8382.	9865.	11504.
10.0	1175.	1739.	2438.	3285.	4266.	5457.	6801.	8328.	10045.	11961.	14083.	16417.
15.0	1450.	2141.	3002.	4044.	5280.	6717.	8374.	10253.	12368.	14727.	17339.	20213.
20.0	1680.	2482.	3479.	4687.	6119.	7788.	9705.	11884.	14335.	17069.	20096.	23427.
30.0	2069.	3056.	4284.	5771.	7534.	9588.	11950.	14632.	17649.	21015.	24743.	28844.
40.0	2398.	3542.	4965.	6689.	8732.	11113.	13850.	16959.	20456.	24357.	28677.	33431.
50.0	2689.	3971.	5567.	7500.	9791.	12461.	15530.	19016.	22937.	27311.	32156.	37486.
75.0	3310.	4889.	6855.	9234.	12055.	15342.	19120.	23412.	28240.	33626.	39590.	46153.
100.0	4724.	6977.	9782.	13177.	17203.	21894.	27285.	33410.	40299.	47985.	56496.	65861.
200.0	5475.	8087.	11337.	15273.	19938.	25375.	31624.	38723.	46708.	55616.	65481.	76335.
300.0	6741.	9957.	13959.	18804.	24548.	31243.	38936.	47676.	57508.	68475.	80621.	93985.
400.0	7813.	11540.	16178.	21795.	28452.	36211.	45128.	55258.	66653.	79365.	93442.	108931.
500.0	8761.	12940.	18140.	24438.	31903.	40603.	50601.	61960.	74737.	88990.	104775.	122143.
750.0	10787.	15932.	22335.	30088.	39280.	49991.	62301.	76286.	92018.	109566.	129000.	150384.
1000.0	12502.	18465.	25887.	34873.	45526.	57941.	72209.	88417.	106651.	126991.	149515.	174299.
2000.0	17841.	26350.	36941.	49765.	64966.	82682.	103043.	126173.	152192.	181217.	213360.	248728.
3000.0	21966.	32443.	45482.	61271.	79988.	101800.	126863.	155346.	187382.	223118.	262692.	306238.
4000.0	25459.	37602.	52713.	71015.	92708.	117989.	147043.	180050.	217181.	258599.	304467.	354938.
5000.0	28547.	42163.	59108.	79628.	103952.	132299.	164877.	201887.	243521.	289963.	341394.	397986.

TABLE 11. DIBORANE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 0.7 PPM (1/7 OF 30-MINUTE EEL.

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	799.	1181.	1655.	2230.	2911.	3705.	4617.	5654.	6820.	8120.	9561.	11145.
5.0	1825.	2696.	3780.	5092.	6647.	8460.	10543.	12909.	15572.	18541.	21830.	25449.
10.0	2605.	3847.	5394.	7266.	9435.	12072.	15045.	18422.	22221.	26459.	31152.	36316.
15.0	3207.	4737.	6641.	8946.	11679.	14863.	18523.	22681.	27359.	32576.	38354.	44712.
20.0	3717.	5490.	7697.	10369.	13536.	17227.	21469.	26208.	31710.	37757.	44454.	51823.
30.0	4577.	6760.	9476.	12765.	16666.	21210.	26435.	32307.	39041.	46487.	54732.	63805.
40.0	5304.	7835.	10983.	14796.	19316.	24583.	30637.	37514.	45250.	53880.	63436.	73952.
50.0	5948.	8785.	12315.	16591.	21658.	27565.	34352.	42063.	50738.	60414.	71130.	82921.
75.0	7323.	10816.	15163.	20427.	26666.	33938.	42295.	51789.	62469.	74383.	87576.	102094.
150.0	10450.	15434.	21638.	29149.	38053.	48430.	60356.	73904.	89145.	106146.	124973.	145689.
200.0	12112.	17889.	25079.	33785.	44105.	56132.	69954.	85657.	103321.	123026.	144847.	168858.
300.0	14912.	22025.	30877.	41596.	54303.	69110.	86129.	105462.	127211.	151472.	178338.	207901.
400.0	17284.	25528.	35787.	48211.	62938.	80101.	99826.	122234.	147441.	175560.	206699.	240962.
500.0	19380.	28624.	40128.	54058.	70571.	89816.	111933.	137058.	165323.	196852.	231768.	270187.
750.0	23861.	35242.	49406.	66558.	86889.	110583.	137814.	168749.	203548.	242368.	285356.	332659.
1000.0	27655.	40847.	57263.	77142.	100706.	128168.	159730.	195584.	235918.	280911.	330736.	385561.
2000.0	39465.	58285.	81715.	110083.	143709.	182895.	227937.	279102.	336659.	400863.	471965.	550201.
3000.0	48590.	71766.	100609.	135536.	176937.	225187.	280640.	343635.	414500.	493550.	581091.	677416.
4000.0	56317.	83179.	116609.	157090.	205075.	260998.	325269.	398282.	480416.	572038.	673500.	785144.
5000.0	63147.	93267.	130751.	176142.	229947.	292655.	364718.	446587.	538683.	641416.	755184.	880368.

TABLE 12. ETHYLENE OXIDE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 50 PPM (30-MINUTE SPELL).

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	43.	63.	89.	120.	156.	199.	248.	304.	366.	436.	514.	599.
5.0	98.	145.	203.	274.	357.	455.	567.	694.	837.	996.	1173.	1367.
10.0	140.	207.	290.	390.	510.	649.	808.	990.	1194.	1422.	1674.	1951.
15.0	172.	255.	357.	481.	628.	799.	995.	1219.	1470.	1750.	2061.	2403.
20.0	200.	295.	414.	557.	727.	926.	1154.	1413.	1704.	2029.	2389.	2785.
30.0	246.	363.	509.	686.	896.	1140.	1420.	1739.	2098.	2498.	2941.	3429.
40.0	285.	421.	590.	795.	1038.	1321.	1646.	2016.	2431.	2895.	3409.	3974.
50.0	320.	472.	662.	891.	1164.	1481.	1846.	2260.	2726.	3246.	3822.	4456.
75.0	393.	581.	815.	1098.	1433.	1824.	2273.	2783.	3357.	3997.	4706.	5486.
150.0	562.	829.	1163.	1566.	2045.	2602.	3243.	3971.	4790.	5704.	6715.	7828.
200.0	651.	961.	1348.	1815.	2370.	3016.	3759.	4603.	5552.	6611.	7783.	9073.
300.0	801.	1184.	1659.	2235.	2918.	3714.	4628.	5667.	6836.	8139.	9583.	11171.
400.0	929.	1372.	1923.	2591.	3382.	4304.	5364.	6568.	7923.	9434.	11107.	12948.
500.0	1041.	1538.	2156.	2905.	3792.	4826.	6015.	7365.	8883.	10576.	12454.	14518.
750.0	1282.	1894.	2655.	3576.	4669.	5942.	7405.	9068.	10938.	13023.	15333.	17875.
1000.0	1486.	2195.	3077.	4145.	5411.	6887.	8583.	10510.	12677.	15095.	17772.	20718.
2000.0	2121.	3132.	4391.	5915.	7722.	9828.	12248.	14997.	18090.	21540.	25361.	29565.
3000.0	2611.	3856.	5406.	7283.	9508.	12100.	15080.	18465.	22273.	26521.	31224.	36400.
4000.0	3026.	4470.	6266.	8441.	11020.	14025.	17478.	21401.	25815.	30738.	36190.	42189.
5000.0	3393.	5012.	7026.	9465.	12356.	15725.	19598.	23997.	28946.	34466.	40579.	47306.

TABLE 13. FLUORINE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 2 PPM (1/5 OF 30-MINUTE EEL)

SS LB/MIN.	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	307.	454.	637.	858.	1120.	1425.	1776.	2175.	2623.	3123.	3677.	4287.
5.0	702.	1037.	1454.	1958.	2557.	3254.	4055.	4966.	5990.	7132.	8357.	9789.
10.0	1002.	1480.	2075.	2795.	3649.	4643.	5787.	7086.	8547.	10177.	11582.	13969.
15.0	1234.	1822.	2554.	3441.	4492.	5717.	7125.	8724.	10523.	12530.	14753.	17198.
20.0	1430.	2112.	2960.	3988.	5206.	6626.	8258.	10112.	12197.	14523.	17059.	19933.
30.0	1760.	2600.	3645.	4910.	6410.	8158.	10167.	12450.	15017.	17881.	21053.	24542.
40.0	2040.	3014.	4225.	5691.	7430.	9456.	11784.	14429.	17405.	20725.	24400.	28445.
50.0	[illegible]	3379.	4737.	6381.	8331.	10603.	13213.	16179.	19516.	23238.	27360.	31895.
75.0	[illegible]	4160.	5832.	7857.	10257.	13054.	16269.	19920.	24023.	28611.	33666.	39270.
100.0	[illegible]	[illegible]	[illegible]	11212.	14637.	18626.	23216.	28427.	34289.	40828.	48070.	56039.
200.0	4655.	6881.	9546.	12995.	16965.	21591.	26908.	32947.	39742.	47321.	55715.	64950.
300.0	5736.	8472.	11877.	16000.	20867.	26563.	33129.	40566.	48931.	58263.	68597.	79908.
400.0	6648.	9819.	13765.	18544.	24209.	30810.	38397.	47017.	56712.	67528.	79566.	92685.
500.0	7454.	11010.	15435.	20793.	27145.	34547.	43054.	52719.	63591.	75718.	89148.	103926.
750.0	9178.	13556.	19004.	25601.	33421.	42555.	53009.	64908.	78294.	93225.	109761.	127356.
1000.0	10638.	15711.	22026.	29672.	38736.	49299.	61439.	75231.	90745.	108051.	127216.	148304.
2000.0	15180.	22420.	31431.	42343.	55277.	70551.	87675.	107355.	129494.	154190.	181539.	211632.
3000.0	18690.	27604.	38699.	52133.	68058.	86617.	107947.	132177.	159435.	189841.	223514.	260565.
4000.0	21662.	31994.	44853.	60424.	78881.	100392.	125113.	153197.	184790.	220031.	259058.	302002.
5000.0	24289.	35875.	50293.	67752.	88448.	112567.	140287.	171777.	207202.	246717.	290478.	338629.

TABLE 14. FLUX TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 2 PPM (1/5 OF 30-MINUTE FLUORINE EEL).

DELTA-T (DEG F)

SS LB/MIN	-4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	307.	454.	637.	858.	1120.	1425.	1776.	2175.	2623.	3123.	3677.	4287.
5.0	702.	1037.	1454.	1958.	2557.	3254.	4055.	4966.	5990.	7132.	8397.	9789.
10.0	1002.	1480.	2075.	2795.	3649.	4643.	5787.	7086.	8547.	10177.	11982.	13969.
15.0	1234.	1822.	2554.	3441.	4492.	5717.	7125.	8724.	10523.	12530.	14753.	17198.
20.0	1430.	2112.	2960.	3988.	5206.	6626.	8258.	10112.	12197.	14523.	17099.	19933.
30.0	1760.	2600.	3645.	4910.	6410.	8158.	10167.	12450.	15017.	17881.	21053.	24542.
40.0	2040.	3014.	4225.	5691.	7430.	9456.	11784.	14429.	17405.	20725.	24400.	28445.
50.0	2288.	3379.	4737.	6381.	8331.	10603.	13213.	16179.	19516.	23238.	27360.	31895.
75.0	2817.	4160.	5832.	7857.	10257.	13054.	16269.	19920.	24029.	28611.	33686.	39270.
150.0	4020.	5937.	8323.	11212.	14637.	18628.	23216.	28427.	34289.	40828.	48070.	56039.
200.0	4659.	6881.	9646.	12995.	16965.	21591.	26908.	32947.	39742.	47321.	55715.	64950.
300.0	5736.	8472.	11877.	16000.	20887.	26583.	33129.	40566.	48931.	58263.	68597.	79968.
400.0	6648.	9819.	13765.	18544.	24209.	30810.	38397.	47017.	56712.	67528.	79506.	92685.
500.0	7454.	11010.	15435.	20793.	27145.	34547.	43054.	52719.	63591.	75718.	89148.	103926.
750.0	9178.	13556.	19004.	25601.	33421.	42535.	53009.	64908.	78294.	93225.	109761.	127956.
1000.0	10638.	15711.	22026.	29672.	38736.	49299.	61439.	75231.	90745.	108051.	127216.	148304.
2000.0	15180.	22420.	31431.	42343.	55277.	70351.	87675.	107355.	129494.	154190.	181539.	211632.
3000.0	18690.	27604.	38699.	52133.	68058.	86617.	107947.	132177.	159435.	189841.	223514.	260565.
4000.0	21662.	31994.	44853.	60424.	78881.	100392.	125113.	153197.	184790.	220031.	259058.	302002.
5000.0	24289.	35875.	50293.	67752.	88448.	112567.	140287.	171777.	207202.	246717.	290478.	338629.

TABLE 15. FUMING NITRIC ACID TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 3 PPM (30-MINUTE SPEL FOR NITROGEN DIOXIDE).

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	226.	334.	469.	632.	824.	1049.	1308.	1601.	1931.	2300.	2708.	3156.
5.0	517.	764.	1070.	1442.	1883.	2396.	2986.	3656.	4410.	5251.	6183.	7207.
10.0	738.	1090.	1528.	2058.	2686.	3419.	4261.	5217.	6293.	7493.	8823.	10285.
15.0	908.	1342.	1881.	2534.	3308.	4209.	5246.	6424.	7748.	9226.	10862.	12663.
20.0	1053.	1555.	2180.	2937.	3834.	4879.	6080.	7445.	8981.	10693.	12590.	14677.
30.0	1296.	1914.	2684.	3615.	4720.	6007.	7486.	9167.	11057.	13166.	15501.	18070.
40.0	1502.	2219.	3111.	4190.	5470.	6962.	8677.	10624.	12815.	15255.	17966.	20944.
50.0	1684.	2488.	3488.	4699.	6134.	7807.	9729.	11913.	14370.	17110.	20145.	23484.
75.0	2074.	3063.	4294.	5785.	7552.	9612.	11979.	14667.	17692.	21066.	24803.	28914.
150.0	2960.	4371.	6126.	8255.	10777.	13716.	17094.	20931.	25247.	30062.	35394.	41261.
200.0	3430.	5066.	7103.	9568.	12491.	15897.	19812.	24259.	29262.	34842.	41023.	47823.
300.0	4223.	6238.	8745.	11781.	15379.	19573.	24393.	29868.	36028.	42899.	50508.	58880.
400.0	4895.	7230.	10135.	13654.	17825.	22686.	28272.	34618.	41757.	49721.	58540.	68244.
500.0	5489.	8107.	11365.	15310.	19987.	25437.	31701.	38817.	46822.	55751.	65640.	76520.
750.0	6758.	9981.	13992.	18850.	24608.	31318.	39031.	47792.	57647.	68642.	80817.	94213.
1000.0	7832.	11568.	16218.	21848.	28521.	36299.	45238.	55392.	66815.	79557.	93669.	109196.
2000.0	11177.	16508.	23145.	31177.	40700.	51799.	64555.	79045.	95346.	113530.	133666.	155824.
3000.0	13701.	20325.	28494.	38385.	50111.	63776.	79481.	97322.	117392.	139780.	164572.	191853.
4000.0	15950.	23557.	33025.	44490.	58080.	73918.	92120.	112799.	136060.	162008.	190744.	222363.
5000.0	17884.	26414.	37030.	49886.	65124.	82883.	103293.	126479.	152562.	181657.	213878.	249332.

TABLE 16. HYDRAZINE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 20 PPM (30-MINUTE SPEL).

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	103.	152.	213.	287.	375.	477.	595.	728.	879.	1046.	1232.	1436.
5.0	235.	347.	487.	656.	856.	1090.	1358.	1663.	2006.	2389.	2812.	3279.
10.0	336.	496.	695.	936.	1222.	1555.	1938.	2373.	2863.	3409.	4013.	4679.
15.0	413.	610.	856.	1153.	1505.	1915.	2386.	2922.	3525.	4197.	4941.	5760.
20.0	479.	707.	992.	1336.	1744.	2219.	2766.	3387.	4085.	4864.	5727.	6676.
30.0	590.	871.	1221.	1645.	2147.	2733.	3405.	4170.	5030.	5989.	7051.	8220.
40.0	683.	1009.	1415.	1906.	2488.	3167.	3947.	4833.	5830.	6941.	8172.	9527.
50.0	766.	1132.	1587.	2137.	2790.	3551.	4426.	5419.	6537.	7783.	9164.	10683.
75.0	943.	1393.	1953.	2632.	3435.	4372.	5449.	6672.	8048.	9583.	11282.	13153.
150.0	1346.	1988.	2788.	3755.	4902.	6239.	7776.	9521.	11484.	13675.	16100.	18769.
200.0	1560.	2305.	3231.	4352.	5682.	7231.	9012.	11035.	13311.	15849.	18661.	21754.
300.0	1921.	2837.	3978.	5359.	6996.	8903.	11096.	13587.	16389.	19514.	22975.	26784.
400.0	2227.	3289.	4610.	6211.	8108.	10319.	12861.	15747.	18995.	22617.	26629.	31043.
500.0	2497.	3688.	5170.	6964.	9092.	11571.	14420.	17657.	21298.	25360.	29859.	34808.
750.0	3074.	4540.	6363.	8575.	11194.	14246.	17754.	21740.	26223.	31224.	36762.	42856.
1000.0	3563.	5262.	7377.	9938.	12974.	16512.	20578.	25197.	30393.	36190.	42609.	49672.
2000.0	5084.	7509.	10527.	14182.	18514.	23563.	29365.	35957.	43372.	51643.	60803.	70882.
3000.0	6260.	9246.	12961.	17461.	22795.	29011.	36155.	44270.	53400.	63584.	74862.	87271.
4000.0	7255.	10716.	15023.	20238.	26420.	33624.	41904.	51311.	61892.	73695.	86767.	101150.
5000.0	8135.	12016.	16845.	22692.	29624.	37702.	46987.	57534.	69398.	82633.	97290.	113418.

TABLE 17. HYDROGEN CHLORIDE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 5 PPM (30-MINUTE SPEL).

DELTA-T (DEG F)

SS LB/MIN	-4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	255.	377.	528.	712.	929.	1182.	1473.	1804.	2176.	2591.	3051.	3556.
5.0	582.	860.	1206.	1625.	2121.	2699.	3364.	4119.	4969.	5916.	6966.	8121.
10.0	831.	1228.	1721.	2319.	3027.	3852.	4801.	5878.	7091.	8443.	9940.	11588.
15.0	1023.	1511.	2119.	2855.	3727.	4743.	5911.	7237.	8730.	10395.	12239.	14267.
20.0	1186.	1752.	2456.	3309.	4319.	5497.	6851.	8388.	10118.	12048.	14185.	16536.
30.0	1460.	2157.	3024.	4074.	5318.	6768.	8435.	10328.	12458.	14834.	17465.	20360.
40.0	1693.	2500.	3505.	4721.	6164.	7844.	9776.	11970.	14439.	17193.	20242.	23598.
50.0	1898.	2803.	3930.	5294.	6911.	8796.	10962.	13422.	16190.	19278.	22697.	26460.
75.0	2337.	3451.	4838.	6518.	8509.	10829.	13496.	16526.	19934.	23735.	27945.	32577.
100.0	3335.	4925.	6904.	9301.	12143.	15454.	19259.	23582.	28446.	33870.	39878.	46489.
200.0	3865.	5708.	8002.	10780.	14074.	17911.	22322.	27333.	32969.	39257.	46220.	53881.
300.0	4758.	7028.	9853.	13273.	17328.	22053.	27483.	33652.	40592.	48334.	56907.	66340.
400.0	5515.	8146.	11420.	15384.	20083.	25560.	31854.	39004.	47047.	56020.	65956.	76890.
500.0	6184.	9134.	12805.	17250.	22519.	28660.	35717.	43734.	52753.	62814.	73956.	86215.
750.0	7614.	11246.	15765.	21238.	27726.	35286.	43975.	53847.	64951.	77338.	91055.	106149.
1000.0	8825.	13034.	18272.	24616.	32135.	40898.	50969.	62410.	75280.	89637.	105536.	123030.
2000.0	12593.	18600.	26075.	35127.	45857.	58362.	72733.	89060.	107426.	127913.	150601.	175566.
3000.0	15505.	22900.	32104.	43249.	56460.	71856.	89550.	109652.	132264.	157489.	185422.	216159.
4000.0	17970.	26542.	37209.	50126.	65438.	83283.	103791.	127089.	153298.	182534.	214910.	250535.
5000.0	20150.	29761.	41722.	56206.	73375.	93384.	116379.	142503.	171890.	204672.	240975.	280920.

TABLE 18. HYDROGEN FLUORIDE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 5 PPM (30-MINUTE SPEL).

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	267.	394.	553.	745.	973.	1258.	1542.	1889.	2278.	2713.	3194.	3723.
5.0	610.	901.	1263.	1701.	2221.	2826.	3522.	4313.	5202.	6194.	7293.	8502.
10.0	870.	1285.	1802.	2427.	3169.	4033.	5026.	6154.	7423.	8839.	10407.	12132.
15.0	1071.	1582.	2218.	2989.	3901.	4965.	6186.	7577.	9140.	10883.	12813.	14937.
20.0	1242.	1834.	2571.	3464.	4522.	5755.	7172.	8782.	10593.	12613.	14851.	17312.
30.0	1529.	2258.	3166.	4265.	5567.	7086.	8830.	10813.	13042.	15530.	18284.	21315.
40.0	1772.	2617.	3669.	4943.	6453.	8212.	10235.	12532.	15116.	17999.	21192.	24705.
50.0	1987.	2935.	4114.	5542.	7235.	9208.	11476.	14052.	16950.	20182.	23762.	27701.
75.0	2446.	3613.	5065.	6824.	8908.	11336.	14129.	17301.	20869.	24845.	29256.	34106.
150.0	3491.	5156.	7228.	9738.	12712.	16179.	20163.	24689.	29780.	35460.	41749.	48670.
200.0	4046.	5976.	8378.	11286.	14734.	18752.	23369.	28615.	34516.	41099.	48389.	56410.
300.0	4982.	7358.	10315.	13896.	18141.	23088.	28773.	35231.	42497.	50602.	59577.	69453.
400.0	5774.	8528.	11955.	16106.	21026.	26759.	33348.	40834.	49255.	58649.	69051.	80498.
500.0	6474.	9562.	13405.	18059.	23576.	30004.	37393.	45787.	55229.	65762.	77426.	90260.
750.0	7971.	11773.	16505.	22235.	29027.	36942.	46039.	56373.	67999.	80967.	95328.	111130.
1000.0	9239.	13645.	19130.	25771.	33643.	42817.	53360.	65338.	78812.	93843.	110488.	128803.
2000.0	13184.	19472.	27298.	36775.	48009.	61100.	76146.	93239.	112466.	133915.	157668.	183804.
3000.0	16232.	23975.	33610.	45278.	59109.	75228.	93752.	114797.	138471.	164879.	194123.	226302.
4000.0	18814.	27787.	38955.	52478.	68509.	87191.	108662.	133053.	160491.	191099.	224994.	262290.
5000.0	21095.	31157.	43680.	58843.	76818.	97766.	121840.	149190.	179956.	214276.	252282.	294102.

TABLE 19. HYDROGEN SULFIDE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 20 PPM (1/5 OF 30-MINUTE EEL).

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	100.	147.	207.	278.	363.	462.	576.	706.	851.	1014.	1153.	1391.
5.0	226.	337.	472.	636.	830.	1056.	1316.	1611.	1944.	2314.	2725.	3177.
10.0	325.	480.	673.	907.	1184.	1507.	1878.	2299.	2774.	3303.	3888.	4533.
15.0	400.	591.	829.	1117.	1456.	1855.	2312.	2831.	3415.	4066.	4788.	5581.
20.0	464.	665.	961.	1294.	1690.	2150.	2680.	3281.	3958.	4713.	5549.	6469.
30.0	571.	844.	1183.	1594.	2080.	2648.	3300.	4040.	4873.	5803.	6832.	7964.
40.0	662.	978.	1371.	1847.	2411.	3069.	3824.	4683.	5648.	6725.	7918.	9231.
50.0	742.	1097.	1537.	2071.	2704.	3441.	4288.	5251.	6333.	7541.	8879.	10351.
75.0	914.	1350.	1893.	2550.	3329.	4236.	5277.	6465.	7798.	9285.	10932.	12744.
150.0	1304.	1927.	2701.	3639.	4750.	6045.	7534.	9225.	11127.	13250.	15600.	18186.
200.0	1512.	2233.	3130.	4217.	5505.	7007.	8732.	10692.	12897.	15357.	18080.	21078.
300.0	1861.	2749.	3854.	5192.	6778.	8627.	10751.	13164.	15879.	18907.	22261.	25951.
400.0	2157.	3186.	4467.	6018.	7856.	9999.	12461.	15258.	18404.	21914.	25801.	30078.
500.0	2419.	3573.	5009.	6748.	8809.	11211.	13972.	17108.	20636.	24572.	28930.	33726.
750.0	2978.	4399.	6167.	8308.	10846.	13803.	17203.	21064.	25408.	30253.	35619.	41524.
1000.0	3452.	5099.	7148.	9629.	12571.	15999.	19938.	24414.	29448.	35064.	41284.	48127.
2000.0	4926.	7276.	10200.	13741.	17936.	22830.	28452.	34839.	42023.	50038.	58913.	68678.
3000.0	6065.	8958.	12556.	16918.	22086.	28109.	35031.	42894.	51740.	61607.	72534.	84558.
4000.0	7030.	10383.	14556.	19609.	25598.	32579.	40601.	49715.	59968.	71404.	84069.	98005.
5000.0	7882.	11642.	16321.	21987.	28703.	36530.	45526.	55745.	67241.	80064.	94265.	109891.

TABLE 20. MAF-1, 3, AND 4 TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 50 PPM (30-MINUTE SPEL FOR UDMH).

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	47.	69.	97.	130.	170.	216.	269.	330.	398.	474.	558.	650.
5.0	106.	157.	220.	297.	388.	493.	613.	753.	908.	1081.	1273.	1484.
10.0	152.	224.	315.	424.	553.	704.	877.	1074.	1296.	1543.	1817.	2118.
15.0	187.	276.	387.	522.	681.	867.	1080.	1323.	1595.	1900.	2237.	2607.
20.0	217.	320.	449.	605.	789.	1005.	1252.	1533.	1849.	2202.	2552.	3022.
30.0	267.	354.	553.	744.	972.	1237.	1541.	1887.	2277.	2711.	3152.	3721.
40.0	305.	457.	640.	863.	1126.	1454.	1787.	2188.	2639.	3142.	3655.	4312.
50.0	347.	512.	718.	967.	1263.	1607.	2003.	2453.	2959.	3523.	4148.	4835.
75.0	427.	631.	884.	1191.	1555.	1979.	2466.	3020.	3643.	4338.	5107.	5953.
150.0	609.	900.	1262.	1700.	2219.	2824.	3520.	4310.	5198.	6190.	7288.	8490.
200.0	706.	1043.	1462.	1970.	2572.	3273.	4079.	4995.	6025.	7174.	8447.	9847.
300.0	870.	1284.	1801.	2426.	3167.	4050.	5022.	6150.	7418.	8833.	10400.	12123.
400.0	1008.	1489.	2087.	2811.	3670.	4671.	5821.	7128.	8598.	10238.	12053.	14051.
500.0	1130.	1669.	2340.	3152.	4115.	5237.	6527.	7992.	9641.	11479.	13515.	15756.
750.0	1391.	2055.	2881.	3881.	5067.	6448.	8036.	9840.	11870.	14133.	16640.	19399.
1000.0	1613.	2382.	3339.	4498.	5873.	7474.	9314.	11405.	13757.	16381.	19286.	22483.
2000.0	2301.	3399.	4765.	6419.	8380.	10665.	13292.	16275.	19632.	23376.	27522.	32084.
3000.0	2833.	4185.	5867.	7904.	10318.	13131.	16365.	20039.	24171.	28781.	33885.	39503.
4000.0	3284.	4850.	6800.	9160.	11959.	15220.	18968.	23225.	28015.	33356.	39274.	45785.
5000.0	3682.	5439.	7625.	10271.	13409.	17066.	21268.	26042.	31412.	37403.	44037.	51337.

TABLE 21. METHYLENE CHLORIDE TCC TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 400 PPM (1/5 OF 30-MINUTE EEL).

DELTA-T (DEG F)

SS LB/MIN	-4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	13.	20.	28.	37.	49.	62.	73.	95.	115.	136.	161.	187.
5.0	31.	45.	63.	86.	112.	142.	177.	217.	262.	311.	367.	427.
10.0	44.	65.	91.	122.	159.	203.	253.	309.	373.	444.	523.	610.
15.0	54.	80.	112.	150.	196.	250.	311.	381.	460.	547.	644.	751.
20.0	62.	92.	129.	174.	227.	289.	361.	442.	533.	634.	747.	871.
30.0	77.	114.	159.	214.	280.	356.	444.	544.	656.	781.	919.	1072.
40.0	89.	132.	185.	249.	324.	413.	515.	630.	760.	905.	1066.	1242.
50.0	100.	148.	207.	279.	364.	463.	577.	707.	852.	1015.	1195.	1393.
75.0	123.	182.	255.	343.	448.	570.	710.	870.	1049.	1253.	1471.	1715.
150.0	176.	259.	363.	490.	639.	814.	1014.	1241.	1497.	1783.	2099.	2447.
200.0	203.	301.	421.	568.	741.	943.	1175.	1439.	1736.	2067.	2433.	2837.
300.0	251.	370.	519.	699.	912.	1161.	1447.	1772.	2137.	2544.	2996.	3492.
400.0	290.	429.	601.	810.	1057.	1346.	1677.	2053.	2477.	2949.	3472.	4048.
500.0	326.	481.	674.	908.	1185.	1509.	1880.	2302.	2777.	3307.	3893.	4539.
750.0	401.	592.	830.	1118.	1460.	1858.	2315.	2835.	3419.	4071.	4794.	5588.
1000.0	465.	686.	962.	1296.	1692.	2153.	2683.	3286.	3963.	4719.	5556.	6477.
2000.0	663.	979.	1373.	1849.	2414.	3072.	3829.	4688.	5655.	6734.	7928.	9243.
3000.0	816.	1200.	1690.	2277.	2972.	3783.	4714.	5773.	6963.	8291.	9761.	11380.
4000.0	946.	1397.	1959.	2639.	3445.	4384.	5464.	6691.	8070.	9609.	11314.	13189.
5000.0	1061.	1567.	2196.	2959.	3863.	4916.	6127.	7502.	9049.	10775.	12686.	14789.

TABLE 22. MONOMETHYLHYDRAZINE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 30 PPM (30-MINUTE SPEL).

DELTA-T (DEG F)

LB/MIN	-4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	79.	103.	144.	194.	253.	322.	401.	491.	592.	705.	830.	968.
5.0	159.	234.	328.	442.	577.	735.	916.	1121.	1352.	1610.	1896.	2210.
10.0	226.	334.	468.	631.	824.	1049.	1307.	1600.	1930.	2298.	2706.	3154.
15.0	279.	411.	577.	777.	1014.	1291.	1607.	1970.	2376.	2829.	3331.	3883.
20.0	323.	477.	668.	901.	1176.	1496.	1865.	2283.	2754.	3279.	3861.	4501.
30.0	396.	587.	823.	1109.	1447.	1842.	2293.	2811.	3391.	4038.	4754.	5542.
40.0	461.	680.	954.	1285.	1676.	2135.	2661.	3258.	3930.	4680.	5510.	6423.
50.0	517.	763.	1070.	1441.	1881.	2394.	2984.	3653.	4407.	5247.	6178.	7202.
75.0	636.	939.	1317.	1774.	2316.	2948.	3674.	4498.	5426.	6461.	7606.	8867.
100.0	908.	1341.	1879.	2532.	3305.	4206.	5242.	6419.	7743.	9219.	10855.	12654.
200.0	1052.	1554.	2178.	2934.	3831.	4875.	6076.	7440.	8974.	10685.	12581.	14666.
300.0	1265.	1913.	2682.	3613.	4716.	6003.	7481.	9160.	11049.	13156.	15490.	18057.
400.0	1501.	2217.	3108.	4187.	5466.	6957.	8670.	10617.	12806.	15248.	17953.	20929.
500.0	1683.	2486.	3485.	4695.	6129.	7801.	9722.	11904.	14359.	17098.	20130.	23467.
750.0	2072.	3061.	4291.	5781.	7547.	9605.	11970.	14657.	17679.	21051.	24785.	28893.
1000.0	2402.	3548.	4974.	6700.	8747.	11132.	13873.	16987.	20491.	24398.	28726.	33488.
2000.0	3428.	5063.	7097.	9561.	12482.	15886.	19797.	24241.	29240.	34817.	40992.	47788.
3000.0	4220.	6233.	8738.	11772.	15368.	19559.	24375.	29846.	36001.	42867.	50471.	58837.
4000.0	4891.	7224.	10128.	13644.	17812.	22669.	28251.	34593.	41726.	49684.	58497.	68194.
5000.0	5485.	8101.	11356.	15299.	19972.	25418.	31678.	38788.	46787.	55710.	65591.	76464.

TABLE 23. NITROGEN DIOXIDE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 3 PPM (30-MINUTE SPEL).

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	226.	334.	469.	632.	924.	1049.	1308.	1601.	1931.	2300.	2708.	3156.
5.0	517.	764.	1070.	1442.	1883.	2396.	2986.	3656.	4410.	5251.	6183.	7207.
10.0	739.	1050.	1528.	2058.	2686.	3419.	4261.	5217.	6293.	7493.	8823.	10285.
15.0	908.	1342.	1831.	2534.	3306.	4209.	5246.	6424.	7748.	9226.	10862.	12663.
20.0	1053.	1555.	2180.	2937.	3834.	4879.	6080.	7445.	8981.	10693.	12590.	14677.
30.0	1296.	1914.	2684.	3615.	4720.	6007.	7486.	9167.	11057.	13166.	15501.	18070.
40.0	1502.	2219.	3111.	4190.	5470.	6962.	8677.	10624.	12815.	15259.	17966.	20944.
50.0	1684.	2488.	3488.	4699.	6134.	7807.	9729.	11913.	14370.	17110.	20145.	23484.
75.0	2074.	3063.	4294.	5785.	7552.	9612.	11979.	14667.	17692.	21066.	24803.	28914.
100.0	2560.	4371.	6128.	8255.	10777.	13716.	17094.	20931.	25247.	30062.	35394.	41261.
200.0	3430.	5066.	7103.	9568.	12491.	15897.	19812.	24259.	29262.	34842.	41023.	47823.
300.0	4223.	6238.	8745.	11781.	15379.	19573.	24393.	29868.	36028.	42899.	50508.	58880.
400.0	4895.	7230.	10135.	13654.	17825.	22686.	28272.	34618.	41757.	49721.	58540.	68244.
500.0	5489.	8107.	11365.	15310.	19987.	25437.	31701.	38817.	46822.	55751.	65640.	76520.
750.0	6758.	9981.	13992.	18850.	24608.	31318.	39031.	47792.	57647.	68642.	80817.	94213.
1000.0	7832.	11568.	16218.	21848.	28521.	36299.	45238.	55392.	66815.	79557.	93669.	109196.
2000.0	11177.	16508.	23143.	31177.	40700.	51799.	64555.	79045.	95346.	113530.	133666.	155824.
3000.0	13761.	20325.	28494.	38385.	50111.	63776.	79481.	97322.	117392.	139780.	164572.	191853.
4000.0	15950.	23557.	33025.	44490.	58080.	73918.	92120.	112799.	136060.	162006.	190744.	222363.
5000.0	17884.	26414.	37030.	49886.	65124.	82883.	103293.	126479.	152562.	181657.	213878.	249332.

TABLE 24. NITROGEN TETROXIDE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 3 PPM (30-MINUTE SPEL FOR NITROGEN DIOXIDE).

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	226.	334.	469.	632.	824.	1049.	1308.	1601.	1931.	2300.	2708.	3156.
5.0	517.	764.	1070.	1442.	1883.	2396.	2986.	3656.	4410.	5251.	6183.	7207.
10.0	738.	1090.	1528.	2058.	2686.	3419.	4261.	5217.	6293.	7493.	8823.	10285.
15.0	908.	1342.	1881.	2534.	3306.	4209.	5246.	6424.	7748.	9226.	10862.	12663.
20.0	1053.	1555.	2180.	2937.	3834.	4879.	6080.	7445.	8981.	10693.	12590.	14677.
30.0	1296.	1914.	2684.	3615.	4720.	6007.	7486.	9167.	11057.	13166.	15501.	18070.
40.0	1502.	2219.	3111.	4190.	5470.	6962.	8677.	10624.	12815.	15259.	17966.	20944.
50.0	1684.	2488.	3488.	4699.	6134.	7807.	9729.	11913.	14370.	17110.	20145.	23484.
75.0	2074.	3063.	4294.	5785.	7552.	9612.	11979.	14667.	17692.	21066.	24803.	28914.
150.0	2960.	4371.	6128.	8255.	10777.	13716.	17094.	20931.	25247.	30062.	35394.	41261.
200.0	3430.	5066.	7103.	9568.	12491.	15897.	19812.	24259.	29262.	34842.	41023.	47823.
300.0	4223.	6238.	8745.	11781.	15379.	19573.	24393.	29868.	36028.	42899.	50508.	58880.
400.0	4895.	7230.	10135.	13654.	17825.	22686.	28272.	34618.	41757.	49721.	58540.	68244.
500.0	5489.	8107.	11365.	15310.	19987.	25437.	31701.	38817.	46822.	55751.	65640.	76520.
750.0	6758.	9981.	13992.	18850.	24608.	31318.	39031.	47792.	57647.	68642.	80817.	94213.
1000.0	7832.	11568.	16218.	21846.	28521.	36299.	45238.	55392.	66815.	79557.	93669.	109196.
2000.0	11177.	16508.	23143.	31177.	40700.	51799.	64555.	79045.	95346.	113530.	133666.	155824.
3000.0	13761.	20325.	28494.	38385.	50111.	63776.	79481.	97322.	117392.	139780.	164572.	191853.
4000.0	15950.	23557.	33025.	44490.	58080.	73918.	92120.	112799.	136060.	162008.	190744.	222363.
5000.0	17884.	26414.	37030.	49886.	65124.	82863.	103293.	126479.	152562.	181657.	213878.	249332.

TABLE 25. OXYGEN DIFLUORIDE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND .1 PPM (1/2 OF 30-MINUTE EEL).

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	1194.	1763.	2472.	3330.	4348.	5533.	6896.	8444.	10185.	12127.	14278.	16645.
5.0	2726.	4026.	5645.	7604.	9927.	12634.	15745.	19280.	23256.	27691.	32603.	38007.
10.0	3890.	5746.	8055.	10851.	14166.	18029.	22469.	27513.	33186.	39515.	46524.	54236.
15.0	4790.	7074.	9918.	13361.	17442.	22198.	27664.	33874.	40860.	48652.	57281.	66777.
20.0	5551.	8199.	11495.	15485.	20215.	25728.	32064.	39261.	47357.	56389.	66391.	77396.
30.0	6835.	10095.	14153.	19066.	24890.	31677.	39477.	48339.	58307.	69427.	81742.	95291.
40.0	7922.	11701.	16403.	22098.	28848.	36714.	45755.	56026.	67580.	80466.	94741.	110445.
50.0	8883.	13120.	18393.	24778.	32346.	41167.	51304.	62821.	75776.	90227.	106231.	123840.
75.0	10937.	16153.	22645.	30507.	39826.	50686.	63167.	77346.	93297.	111089.	130793.	152474.
150.0	15607.	23051.	32315.	43534.	56832.	72329.	90140.	110374.	133136.	158526.	186644.	217583.
200.0	18089.	26717.	37454.	50457.	65869.	83831.	104475.	127926.	154308.	183736.	216325.	252185.
300.0	22271.	32894.	46114.	62123.	81100.	103215.	128631.	157505.	189986.	226219.	266344.	310495.
400.0	25813.	38125.	53448.	72002.	93997.	119629.	149087.	182553.	220199.	262194.	308700.	359872.
500.0	28943.	42749.	59930.	80735.	105397.	134138.	167169.	204693.	246906.	293994.	346135.	403518.
750.0	35636.	52633.	73787.	99402.	129766.	165153.	205821.	252022.	303995.	361970.	426173.	496818.
1000.0	41303.	61003.	85521.	115210.	150405.	191416.	238553.	292101.	352338.	419533.	493946.	575826.
2000.0	58940.	87053.	122040.	164406.	214627.	273154.	340418.	416832.	502791.	598680.	704868.	821711.
3000.0	72567.	107181.	150257.	202420.	264252.	336312.	419128.	513210.	619045.	737105.	867845.	1011705.
4000.0	84108.	124225.	174152.	234610.	306275.	389795.	485781.	594825.	717491.	854324.	1005856.	1172593.
5000.0	94308.	139292.	195274.	263064.	343421.	437070.	544698.	666966.	804510.	957939.	1127849.	1314808.

TABLE 26. PERCHLOROETHYLENE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 80 PPM (1/5 OF 30-MINUTE ELL).

DELTA-T (DEG F)

SS LB/MIN	-4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	22.	32.	45.	61.	79.	101.	126.	154.	186.	222.	261.	304.
5.0	50.	74.	103.	139.	181.	231.	288.	352.	425.	506.	596.	695.
10.0	71.	105.	147.	198.	259.	330.	411.	503.	607.	722.	850.	991.
15.0	88.	129.	181.	244.	319.	406.	506.	619.	747.	885.	1047.	1221.
20.0	101.	150.	210.	283.	370.	470.	586.	718.	866.	1031.	1214.	1415.
30.0	125.	185.	259.	349.	455.	579.	722.	884.	1066.	1265.	1494.	1742.
40.0	145.	214.	300.	404.	527.	671.	836.	1024.	1235.	1471.	1732.	2019.
50.0	162.	240.	336.	453.	591.	755.	938.	1148.	1385.	1649.	1942.	2264.
75.0	200.	295.	414.	558.	728.	927.	1155.	1414.	1705.	2031.	2391.	2787.
100.0	285.	421.	591.	796.	1039.	1322.	1648.	2018.	2434.	2898.	3412.	3977.
200.0	331.	488.	685.	922.	1204.	1532.	1910.	2339.	2821.	3359.	3954.	4610.
300.0	407.	601.	843.	1136.	1483.	1887.	2351.	2879.	3473.	4135.	4865.	5676.
400.0	472.	697.	977.	1316.	1718.	2187.	2725.	3337.	4025.	4793.	5643.	6579.
500.0	529.	781.	1096.	1476.	1927.	2452.	3056.	3742.	4513.	5374.	6327.	7376.
750.0	651.	962.	1349.	1817.	2372.	3019.	3762.	4607.	5557.	6617.	7791.	9082.
1000.0	755.	1115.	1563.	2106.	2749.	3499.	4361.	5340.	6441.	7669.	9029.	10526.
2000.0	1077.	1591.	2231.	3005.	3923.	4993.	6223.	7620.	9191.	10944.	12885.	15021.
3000.0	1327.	1959.	2747.	3700.	4831.	6148.	7662.	9382.	11316.	13474.	15864.	18494.
4000.0	1537.	2271.	3184.	4289.	5599.	7125.	8880.	10873.	13116.	15617.	18387.	21435.
5000.0	1724.	2546.	3570.	4809.	6278.	7990.	9957.	12192.	14707.	17511.	20617.	24035.

TABLE 27. PERCHLORYL FLUORIDE TLL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 4 PPM (1/5 OF 30-MINUTE EEL).

DELTA-T (DEG F)

SS LB/MIN	-4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	130.	191.	268.	361.	472.	600.	748.	916.	1105.	1316.	1549.	1806.
5.0	296.	437.	612.	825.	1077.	1371.	1706.	2092.	2523.	3005.	3538.	4124.
10.0	422.	623.	874.	1177.	1537.	1958.	2438.	2985.	3601.	4288.	5048.	5885.
15.0	520.	768.	1076.	1450.	1893.	2409.	3002.	3676.	4433.	5279.	6215.	7246.
20.0	602.	890.	1247.	1680.	2193.	2792.	3479.	4260.	5139.	6119.	7204.	8398.
30.0	742.	1095.	1536.	2069.	2701.	3437.	4284.	5245.	6327.	7533.	8869.	10340.
40.0	860.	1270.	1780.	2398.	3130.	3984.	4965.	6079.	7333.	8731.	10280.	11984.
50.0	964.	1424.	1996.	2689.	3510.	4467.	5567.	6816.	8222.	9790.	11527.	13437.
75.0	1187.	1753.	2457.	3310.	4321.	5500.	6854.	8392.	10123.	12054.	14192.	16544.
100.0	1393.	2501.	3506.	4724.	6167.	7848.	9781.	11976.	14446.	17201.	20252.	23609.
200.0	1963.	2899.	4064.	5475.	7147.	9096.	11336.	13881.	16743.	19936.	23473.	27365.
[illegible]	2417.	3569.	5004.	6741.	8800.	11199.	13957.	17090.	20615.	24546.	28900.	33690.
[illegible]	2801.	4137.	5799.	7813.	10199.	12980.	16177.	19808.	23893.	28450.	33496.	39049.
[illegible]	3141.	4638.	6503.	8760.	11456.	14555.	18139.	22210.	26791.	31900.	37558.	43784.
750.0	3867.	5711.	8006.	10786.	14080.	17920.	22333.	27346.	32985.	39276.	46242.	53906.
[illegible]	4492.	6619.	9280.	12501.	16320.	20770.	[illegible]	31695.	38231.	45522.	53596.	62480.
[illegible]	[illegible]	9446.	13242.	17839.	[illegible]	[illegible]	[illegible]	[illegible]	54556.	64960.	76482.	89160.
2000.0	7874.	11630.	16304.	21964.	28673.	36492.	[illegible]	[illegible]	67170.	[illegible]	94166.	109776.
4000.0	9126.	13479.	18897.	[illegible]	33233.	42295.	[illegible]	[illegible]	77852.	92695.	109141.	127233.
5000.0	10235.	15114.	21188.	28544.	37263.	47425.	59103.	72370.	87294.	103942.	122378.	142664.

TABLE 28. PENTABORANE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 0.6 PPM (1/7 OF 30-MINUTE EEL).

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	440.	649.	910.	1226.	1600.	2037.	2539.	3108.	3749.	4464.	5256.	6128.
5.0	1004.	1482.	2078.	2799.	3654.	4651.	5796.	7097.	8561.	10194.	12062.	13991.
10.0	1432.	2115.	2965.	3995.	5215.	6637.	8271.	10128.	12217.	14547.	17127.	19966.
15.0	1763.	2604.	3651.	4918.	6421.	8172.	10184.	12470.	15042.	17910.	21087.	24582.
20.0	2044.	3018.	4232.	5701.	7442.	9471.	11804.	14453.	17434.	20758.	24440.	28492.
30.0	2516.	3716.	5210.	7019.	9163.	11661.	14533.	17795.	21465.	25558.	30091.	35080.
40.0	2916.	4307.	6039.	8135.	10620.	13516.	16844.	20625.	24878.	29623.	34877.	40658.
50.0	3270.	4830.	6771.	9121.	11908.	15155.	18887.	23126.	27895.	33215.	39107.	45589.
75.0	4026.	5946.	8336.	11230.	14661.	18659.	23254.	28473.	34345.	40895.	48149.	56130.
150.0	5745.	8486.	11896.	16026.	20921.	26626.	33183.	40632.	49011.	58358.	68709.	80099.
200.0	6659.	9835.	13788.	18575.	24248.	30861.	38460.	47093.	56805.	67639.	79636.	92837.
300.0	8199.	12109.	16976.	22869.	29855.	37996.	47353.	57982.	69939.	83278.	98049.	114302.
400.0	9502.	14035.	19676.	26506.	34603.	44039.	54883.	67203.	81062.	96521.	113641.	132479.
500.0	10655.	15737.	22062.	29721.	38800.	49380.	61540.	75354.	90893.	108227.	127424.	148546.
750.0	13119.	19376.	27163.	36593.	47771.	60797.	75769.	92777.	111909.	133252.	156887.	182893.
1000.0	15205.	22457.	31483.	42412.	55368.	70466.	87818.	107531.	129706.	154442.	181836.	211978.
2000.0	21697.	32047.	44926.	60523.	79010.	100556.	125318.	153448.	185092.	220391.	259482.	302496.
3000.0	26714.	39456.	55314.	74516.	97279.	123806.	154293.	188927.	227888.	271350.	319479.	372438.
4000.0	30962.	45731.	64111.	86367.	112749.	143495.	178830.	218972.	264129.	314501.	370285.	431666.
5000.0	34718.	51277.	71886.	96841.	126423.	160898.	200519.	245530.	296163.	352645.	415194.	484019.

TABLE 29. SULFUR DIOXIDE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 4 PPM (1/5 OF 30-MINUTE EEL).

DELTA-T (DEG F)

SS LB/MIN	-4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	165.	243.	341.	460.	600.	764.	952.	1166.	1406.	1674.	1971.	2298.
5.0	376.	556.	779.	1050.	1371.	1744.	2174.	2662.	3211.	3823.	4501.	5247.
10.0	537.	793.	1112.	1498.	1956.	2469.	3102.	3798.	4582.	5455.	6423.	7488.
15.0	661.	977.	1369.	1845.	2408.	3065.	3819.	4677.	5641.	6717.	7908.	9219.
20.0	766.	1132.	1587.	2138.	2791.	3552.	4427.	5420.	6538.	7785.	9166.	10685.
30.0	944.	1394.	1954.	2632.	3436.	4373.	5450.	6673.	8050.	9585.	11285.	13156.
40.0	1094.	1615.	2265.	3051.	3983.	5069.	6317.	7735.	9330.	11109.	13079.	15248.
50.0	1226.	1811.	2539.	3421.	4466.	5683.	7083.	8673.	10461.	12456.	14666.	17097.
75.0	1516.	2236.	3126.	4212.	5498.	6997.	8721.	10678.	12880.	15337.	18057.	21050.
150.0	2155.	3182.	4461.	6010.	7846.	9985.	12444.	15238.	18380.	21886.	25767.	30039.
200.0	2497.	3688.	5171.	6966.	9094.	11573.	14423.	17661.	21303.	25366.	29865.	34816.
300.0	3075.	4541.	6366.	8576.	11196.	14249.	17758.	21745.	26229.	31231.	36770.	42866.
400.0	3564.	5263.	7379.	9940.	12977.	16515.	20582.	25203.	30400.	36197.	42618.	49682.
500.0	3996.	5902.	8274.	11146.	14551.	18518.	23079.	28259.	34087.	40588.	47787.	55708.
750.0	4920.	7266.	10187.	13723.	17915.	22800.	28415.	34793.	41968.	49972.	58836.	68589.
1000.0	5702.	8422.	11807.	15905.	20764.	26426.	32934.	40326.	48642.	57919.	68192.	79496.
2000.0	8137.	12018.	16848.	22697.	29630.	37711.	46997.	57546.	69413.	82651.	97311.	113442.
3000.0	10018.	14797.	20744.	27945.	36482.	46430.	57863.	70852.	85463.	101762.	119811.	139672.
4000.0	11612.	17150.	24043.	32389.	42283.	53813.	67065.	82119.	99054.	117945.	138864.	161884.
5000.0	13020.	19230.	26959.	36318.	47411.	60340.	75199.	92079.	111067.	132249.	155706.	181517.

TABLE 30. TRICHLOROETHYLENE TLL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 80 PPM (1/5 OF 30-MINUTE EEL).

DELTA-T (DEG F)

SS LB/MIN	-4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	25.	36.	51.	68.	89.	114.	142.	173.	209.	245.	253.	342.
5.0	56.	83.	116.	150.	204.	260.	323.	395.	478.	565.	670.	781.
10.0	80.	118.	165.	223.	291.	370.	462.	565.	682.	812.	956.	1114.
15.0	98.	145.	204.	274.	358.	456.	568.	696.	839.	995.	1177.	1372.
20.0	114.	168.	236.	318.	415.	526.	659.	806.	973.	1156.	1364.	1590.
30.0	140.	207.	291.	392.	511.	651.	811.	993.	1198.	1426.	1675.	1957.
40.0	163.	240.	337.	454.	593.	754.	940.	1151.	1388.	1653.	1946.	2269.
50.0	182.	265.	378.	509.	664.	846.	1054.	1290.	1556.	1853.	2182.	2544.
75.0	225.	332.	465.	627.	818.	1041.	1297.	1539.	1916.	2282.	2686.	3132.
150.0	321.	473.	604.	894.	1167.	1466.	1851.	2207.	2735.	3256.	3834.	4469.
200.0	372.	549.	769.	1036.	1353.	1722.	2146.	2628.	3169.	3774.	4443.	5180.
300.0	457.	676.	947.	1276.	1666.	2120.	2642.	3235.	3902.	4646.	5471.	6377.
400.0	530.	783.	1098.	1479.	1931.	2457.	3062.	3750.	4523.	5285.	6341.	7392.
500.0	594.	878.	1231.	1658.	2165.	2755.	3434.	4204.	5071.	6035.	7110.	8288.
750.0	732.	1081.	1516.	2042.	2665.	3392.	4228.	5176.	6244.	7435.	8754.	10205.
1000.0	848.	1253.	1757.	2366.	3089.	3932.	4900.	6000.	7237.	8617.	10146.	11827.
2000.0	1211.	1788.	2507.	3377.	4408.	5611.	6992.	8562.	10327.	12257.	14478.	16878.
3000.0	1491.	2201.	3086.	4158.	5426.	6908.	8609.	10541.	12715.	15140.	17625.	20780.
4000.0	1728.	2552.	3577.	4819.	6291.	8006.	9978.	12218.	14737.	17546.	20660.	24085.
5000.0	1937.	2861.	4011.	5403.	7054.	8977.	11188.	13699.	16524.	19676.	23166.	27006.

TABLE 31. TRICHLOROTRIFLUOROETHANE TCL TABLE. TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 2000 PPM (1/5 OF 30-MINUTE EEL).

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	4.	6.	8.	11.	14.	18.	23.	28.	33.	40.	47.	55.
5.0	9.	13.	19.	25.	33.	41.	52.	63.	76.	91.	107.	125.
10.0	13.	19.	26.	36.	47.	59.	74.	90.	109.	130.	153.	178.
15.0	16.	23.	33.	44.	57.	73.	91.	111.	134.	160.	188.	219.
20.0	18.	27.	38.	51.	66.	84.	105.	129.	156.	185.	218.	254.
30.0	22.	33.	46.	63.	82.	104.	130.	159.	191.	228.	268.	313.
40.0	26.	38.	54.	73.	95.	121.	150.	184.	222.	264.	311.	363.
50.0	29.	43.	60.	81.	106.	135.	168.	206.	249.	296.	349.	407.
75.0	36.	53.	74.	100.	131.	166.	207.	254.	306.	365.	429.	501.
150.0	51.	76.	106.	143.	187.	238.	296.	362.	437.	521.	613.	714.
200.0	59.	88.	123.	166.	216.	275.	343.	420.	507.	603.	710.	828.
300.0	73.	108.	151.	204.	266.	339.	422.	517.	624.	743.	875.	1020.
400.0	85.	125.	176.	236.	309.	393.	490.	599.	723.	861.	1014.	1182.
500.0	95.	140.	197.	265.	346.	440.	549.	672.	811.	965.	1137.	1325.
750.0	117.	173.	242.	326.	426.	542.	676.	828.	998.	1189.	1399.	1631.
1000.0	136.	200.	281.	378.	494.	629.	783.	959.	1157.	1378.	1622.	1891.
2000.0	194.	286.	401.	540.	705.	897.	1118.	1369.	1651.	1966.	2315.	2698.
3000.0	238.	352.	493.	665.	868.	1104.	1376.	1685.	2033.	2420.	2850.	3322.
4000.0	276.	408.	572.	770.	1006.	1280.	1595.	1953.	2356.	2805.	3303.	3851.
5000.0	310.	457.	641.	864.	1128.	14[illegible].	1789.	2190.	2642.	3146.	3704.	4318.

TABLE 32. UNSYMMETRICAL DIMETHYLHYDRAZINE (UDMH). TOXIC CORRIDOR LENGTHS (FEET) FOR VARIOUS SOURCE STRENGTHS (LB/MIN), DELTA-T (DEG F), AND 50 PPM (30-MINUTE SPEL).

SS LB/MIN	DELTA-T (DEG F) -4.	-3.	-2.	-1.	0.	1.	2.	3.	4.	5.	6.	7.
1.0	47.	69.	97.	130.	170.	216.	269.	330.	398.	474.	558.	650.
5.0	106.	157.	220.	297.	388.	493.	615.	753.	908.	1081.	1273.	1484.
10.0	152.	224.	315.	424.	553.	704.	877.	1074.	1296.	1543.	1817.	2118.
15.0	187.	276.	387.	522.	681.	867.	1080.	1323.	1595.	1900.	2237.	2607.
20.0	217.	320.	449.	605.	789.	1005.	1252.	1533.	1849.	2202.	2592.	3022.
30.0	267.	394.	553.	744.	972.	1237.	1541.	1887.	2277.	2711.	3192.	3721.
40.0	309.	457.	640.	863.	1126.	1434.	1787.	2188.	2639.	3142.	3699.	4312.
50.0	347.	512.	718.	967.	1263.	1607.	2003.	2453.	2959.	3523.	4148.	4835.
75.0	427.	631.	884.	1191.	1555.	1979.	2466.	3020.	3643.	4338.	5107.	5953.
150.0	609.	900.	1262.	1700.	2219.	2824.	3520.	4310.	5198.	6190.	7288.	8496.
200.0	706.	1043.	1462.	1970.	2572.	3273.	4079.	4995.	6025.	7174.	8447.	9847.
300.0	870.	1284.	1801.	2426.	3167.	4030.	5022.	6150.	7418.	8833.	10400.	12123.
400.0	1008.	1489.	2087.	2811.	3670.	4671.	5821.	7128.	8598.	10238.	12053.	14051.
500.0	1130.	1669.	2340.	3152.	4115.	5237.	6527.	7992.	9641.	11479.	13515.	15756.
750.0	1391.	2055.	2881.	3881.	5067.	6448.	8036.	9840.	11870.	14133.	16640.	19399.
1000.0	1613.	2382.	3339.	4498.	5873.	7474.	9314.	11405.	13757.	16381.	19286.	22483.
2000.0	2301.	3399.	4765.	6419.	8380.	10665.	13292.	16275.	19632.	23376.	27522.	32084.
3000.0	2833.	4185.	5867.	7904.	10318.	13131.	16365.	20039.	24171.	28781.	33885.	39503.
4000.0	3284.	4850.	6800.	9160.	11959.	15220.	18968.	23225.	28015.	33358.	39274.	45785.
5000.0	3682.	5439.	7625.	10271.	13409.	17066.	21263.	26042.	31412.	37403.	44037.	51337.

Chapter 5

METHOD 2: CHEMICAL AND DIFFUSION FACTORS

The steps to determine the dimensions of a toxic corridor using this method are presented below. Where applicable, preferred and alternate approaches are given. The Table of Chemical Factors (Table 33) and the Table of Diffusion Factors (Table 34) are required. Two copies of a suggested worksheet are provided in Appendix A; one with a sample corridor calculation (Figure A-1) and one blank copy (Figure A-2). A flow chart for Method 2 is depicted in Figure 2.

a. STEP 1: Determine source strength (lb/min).

(1) Preferred. Obtain a source strength from the disaster response force (DRF). NOTE: Although weather personnel are not responsible for determining source strength, a toxic corridor length calculation cannot be made without it. Appendix C provides an equation for calculating evaporative source strengths based on the surface area covered by the toxic chemical spill. Use this Appendix to assist the agency responsible for estimating source strengths.

(2) Alternate. For small amounts of liquid or gaseous material (less than 2000 lb), assume the worst case which is total release of the material in 1 minute. For large amounts of a gas (2000 lb or more), assume total release over 5 minutes. For large amounts of liquid, assume a source strength of 2000 lb per minute.

(3) Alternate. For releases of a large amount of material where a source strength cannot be determined from the above procedures, go to alternate procedure in Step 5.

b. STEP 2: Determine temperature difference (delta-T ($^{\circ}F$)).

(1) Preferred. Use the mean delta-T based on at least a 10-minute record from a 54-6 foot delta-T instrument. (Available at TITAN II missile sites. Refer to Appendix B, Figure B-1.) NOTE: 54-6 foot delta-T measurements can be made by using a sling psychrometer at the 54- and 6-foot levels of a radar tower.

(2) Alternate. Use mean surface wind speed, solar elevation angle, and sky condition to obtain an estimated temperature difference from Table B-1, Appendix B. Refer to the notes in this table concerning rough terrain and forested regions prior to estimating the temperature difference.

c. STEP 3: Determine the Chemical Factor (CF).

(1) Preferred. Turn to Table of Chemical Factors (Table 33). Find the CF for the particular toxic chemical of concern and the appropriate exposure limit. This will normally be the Short-Term Public Emergency Limit (SPEL). The limit must be expressed in parts per million by volume.

(2) First alternate. If Table 33 does not contain a CF for the particular toxic chemical of concern, the CF may be obtained from Figure 3. Enter the ordinate of Figure 3 with the gram molecular weight (GMW) and project a line across the graph until the line extending from the exposure limit in parts per million is intersected. The value on the diagonal line at the point of intersection is the CF. The Bioenvironmental Engineer (BEE) may be able to provide the GMW and exposure limit for the chemical of concern.

(3) Second alternate. If Table 33 does not contain a CF for the particular toxic chemical of concern, the CF may be calcualted directly using the equation below. The BEE may be able to provide the GMW and exposure limit for the chemical of concern.

$$CF = 30.476\ (Cp \cdot GMW)^{-0.513}$$

where Cp = exposure limit in parts per million by volume, and

GMW = gram molecular weight.

d. STEP 4: Determine the Diffusion Factor (DF).

(1) Preferred. Turn to the Table of Diffusion Factors (DF) (Table 34). Read across from the source strength (Q) determined in Step 1 and down from the temperature difference determined in Step 2. The intersected value is the Diffusion Factor (DF).

(2) First alternate. If Table 34 does not list a DF for the particular chemical of concern, the DF may be obtained from Figure 4. Enter the ordinate of Figure 4 with the source strength from Step 1 and project a line across the graph until the appropriate line representing the temperature difference from Step 2 is intersected. The value of the curved-diagonal line at the point of intersection is the DF.

(3) Second alternate. If Table 34 does not list a DF for the particular chemical of concern, the DF may be calculated directly from the source strength determined in Step 1 and the temperature difference determined in Step 2. Calculate DF using the following equation:

$$DF = Q^{0.513} (\Delta T + 10)^{2.53}$$

where Q = the source strength in pounds per minute, and

ΔT = the 54-6 foot temperature difference in degrees F.

e. STEP 5: Determine Toxic Corridor Length (TCL).

(1) Preferred. Toxic corridor length is the product of the chemical factor from Step 3 and the Diffusion Factor from Step 4, i.e., TCL = CF · DF.

(2) Alternate. For releases of a large amount of material where no source strength is available, use the distance the wind would carry the material in one hour. This is an interim forecast which must be updated when particulars are known.

f. STEP 6: Determine wind direction and wind direction variability, R (degrees of azimuth). If the surface wind is equal to or less than 3 knots, go to Step 8.

(1) Preferred. Use the 10-minute recorded wind direction trace and eliminate the two furthest direction fluctuations on each side of the mean. Variability, R, is the difference in degrees between the third largest fluctuation on each side of the mean direction.

(2) Alternate. Note the wind fluctuations indicated by an anemometer dial over a 2-minute period. Variability, R, is the difference in degrees between the largest fluctuation on each side of the mean direction.

(3) Approximate. If wind direction fluctuation information is unavailable, assume R is 60° when the wind speed is between 4 and 10 knots; assume R is 30° when the wind speed is greater than 10 knots.

g. STEP 7: Determine corridor width (W) in degrees by multiplying the value obtained for R in Step 6 by 1.5.

h. STEP 8: Plot the toxic corridor.

(1) Wind speed greater than 3 knots. Draw the corridor center line from the source to the point on the wind direction circle corresponding to the direction the mean wind is blowing towards (i.e., 180 degrees from the recorded mean wind direction), as determined in Step 6. Place W/2, calculated in Step 7, on each side of the center line. Draw the lines which define each side of the corridor. See example worksheet, Figure A-1 in Appendix A.

(2) Wind speed equal to or less than 3 knots The corridor is a circle of radius equal to the corridor length determined in Step 5.

i. STEP 9: Trend forecast. If significant changes in wind direction are expected within the next hour or two, include this information in your briefing. A change in direction that would affect evacuation is significant. Based on continued close monitoring of weather conditions, relay any significant changes in the toxic corridor forecast to the DRF. Consider changes in winds that have occurred between the time of the spill and the time of the forecast. These changes could alter the shape and size of the toxic corridor.

TOXIC CORRIDOR CALCULATIONS
USING METHOD 2

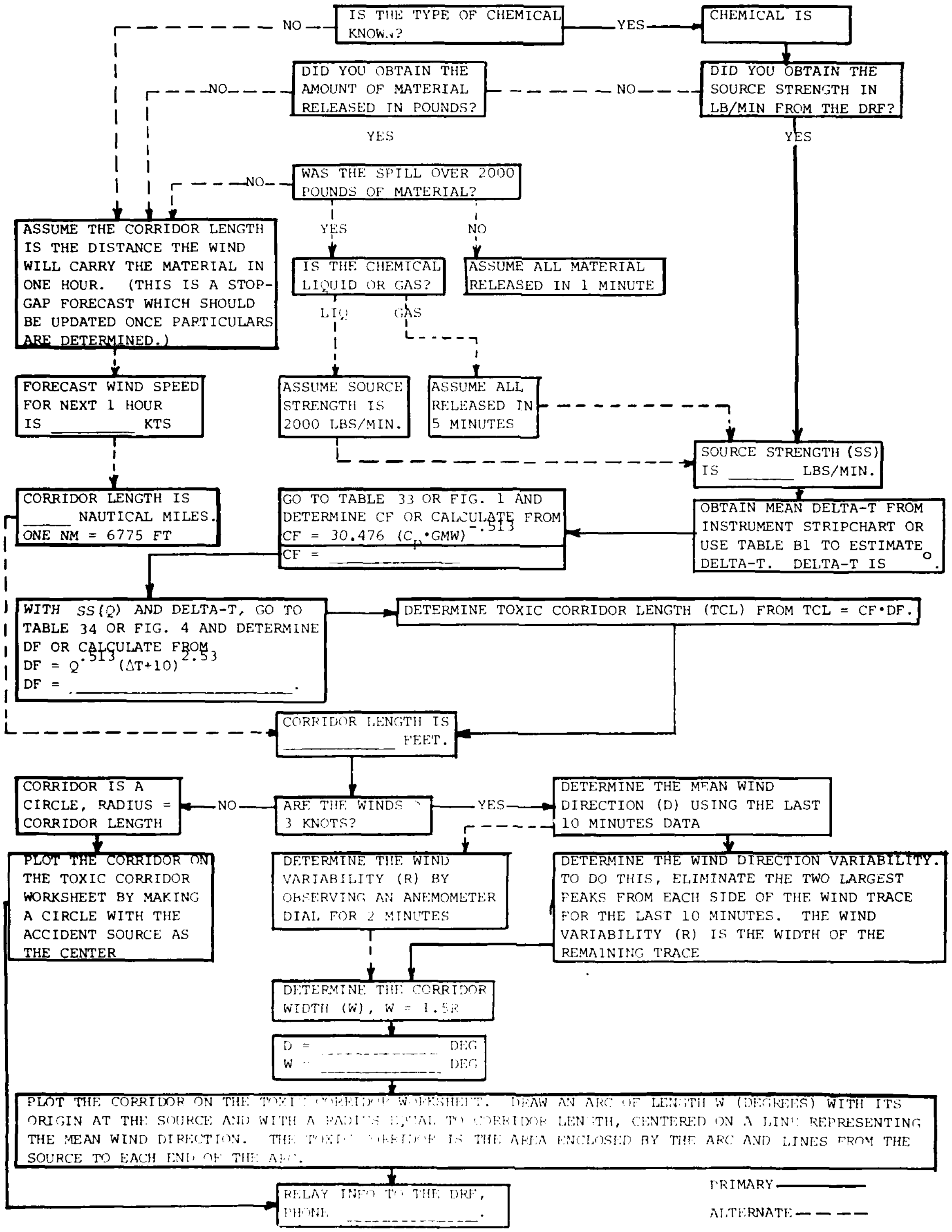


Figure 2. Flow Chart for Method 2.

Table 33. Table of Chemical Factors.

		CHEMICAL FACTORS (CF)						
TOXIC CHEMICAL	GMW	30-min SPEL (PPM)	CF	30-min EEL (PPM)	CF	10-min STPL (PPM)	CF	REMARKS
Aerozine 50 (50% Hydrazine/50% UDMH)	N/A	*	*	*	*	*	*	*Use CF for hydrazine
Anhydrous Ammonia	17.031	75.0[1]	0.78	300.0[1]	0.38	20.0[1]	1.53	
Aniline	93.129	20.0[3]	0.64	100.0[2]	0.28	None	-	
Bromine Pentafluoride	174.896	0.3[3]	4.0	1.5[1] (T)	1.75	None	-	(T) - Tentative
Carbon Disulfide	76.139	20.0[3]	0.71	100.0[1]	0.31	None	-	
Carbon Monoxide	28.011	100.0[1]	0.52	500.0[1]	0.23	90.0[1]	0.55	
Chlorine	70.906	2.0[1]	2.40	see remarks	1.94*	1.0	3.42	*60-min EEL: 3.0 ppm
Chlorine Pentafluoride	130.445	0.3[3]	4.64	1.5[1] (T)	2.03	None	-	(T) - Tentative
Chlorine Trifluoride	92.448	0.6[3]	3.88	3.0[1]	1.70	None	-	
Diborane	16.859	0.7[4]	8.59	5.0[1]	3.76	None	-	
Ethylene Oxide	44.054	80.0[3]	0.46	400.0[1]	0.20	None	-	
Fluorine	37.997	2.0[3]	3.30	10.0[1]	1.45	None	-	
FLOX (Fluorine/Oxygen Mixture)	N/A	*	*	*	*	None	-	*Use CF for fluorine
Fuming Nitric Acid	N/A	*	*	*	*	*	*	*Use CF for Nitrogen Dioxide
H-70 (70% Hydrazine/30% Water)	N/A	*	*	*	*	*	*	*Use CF for Hydrazine
Hydrazine	32.045	20.0[1]	1.11	20.0[1]	1.11	15.0[1]	1.28	Tentative limits 1/10 of existing
Hydrogen Chloride	36.461	3.0[1]	2.74	50.0[1]	0.65	4.0[1]	2.43	
Hydrogen Fluoride	20.006	5.0[1]	2.87	10.0[1]	2.01	4.0[1]	3.22	
Hydrogen Sulfide	34.080	20.0[3]	1.07	100.0[1]	0.47	None	-	
MAF 1, 3, and 4 (Mixed Amine Fuels)	N/A	*	*	*	*	*	*	*Use CF for UDMH
Methylene chloride	84.933	400.0[3]	0.14	2000.0[2]	0.06	None	-	
Monomethylhydrazine (MMD)	46.072	30.0[1]	0.75	30.0[1]	0.75	9.0[1]	1.38	
Nitrogen Dioxide	46.006	3.0[1]	2.43	20.0[1]	0.92	1.0[1]	4.27	
Nitrogen Tetroxide	N/A	*	*	*	*	*	*	*Use CF for Nitrogen Dioxide
Nitrogen Trifluoride	71.002	150.0[3]	0.26	750.0[1]	0.11	None	-	
Oxygen Difluoride	53.996	0.1[5]	12.83	0.2[1]	8.99	None	-	
Perch loroethylene	164.902	80.0[3]	0.23	400.0[2]	0.10	None	-	
Perchloryl Fluoride	102.450	4.0[3]	1.39	20.0[1]	0.61	None	-	
Pentaborane	63.127	0.6[4]	4.72	4.0[2]	1.78	None	-	
Sulfur Dioxide	64.063	4.0[3]	1.77	20.0[1]	0.78	None	-	
Trichlorethylene	131.389	80.0[3]	0.26	400.0[2]	0.12	None	-	
Trichlorotrifluoro-ethane	187.377	2000.0[3]	0.042	10,000.0[2]	0.018	None	-	
Unsymmetrical Di-methylhydrazine	60.099	50.0[1]	0.50	50.0[1]	0.50	50.0[1]	0.50	

Notes:
1. From Committee on Toxicology (EELs from Nov 79 listing; SPELs/STPLs from Jul 80 listing.)
2. From AFM 161-30, Vol II, "Liquid Propellants," 10 Apr 73.
3. 1/5 of 30-minute EEL.
4. 1/7 of 30-minute EEL.
5. 1/2 of 30-minute EEL.

Table 34. Table of Diffusion Factors (DF). The DF is a function of Temperature Difference (ΔT) Source Strength (Q).

$$DF = Q^{0.513} (\Delta T + 10)^{2.53}.$$

SOURCE STRENGTH LB/MIN	DELTA T (DEG F) -4	-3	-2	-1	0	1	2	3	4	5	6	7
0.01	9	13	19	25	32	41	51	62	75	90	105	123
0.05	21	30	42	56	73	93	116	142	171	240	240	280
0.10	29	43	60	80	104	133	165	202	244	291	342	399
0.50	66	97	136	182	238	303	377	462	557	663	780	910
1.0	94	138	193	260	339	432	538	659	794	946	1113	1298
5.0	213	314	440	593	774	985	1228	1503	1813	2159	2541	2963
10.0	304	448	628	846	1105	1406	1752	2145	2587	3080	3626	4228
15.0	374	552	773	1042	1360	1731	2157	2641	3185	3792	4465	5205
20.0	433	640	896	1207	1576	2006	2499	3060	3691	4395	5175	6033
30.0	533	787	1104	1486	1940	2469	3077	3768	4545	5411	6371	7427
40.0	618	912	1279	1723	2249	2862	3567	4367	5267	6272	7384	8608
50.0	693	1023	1434	1932	2521	3209	3999	4897	5906	7033	8280	9652
75.0	853	1259	1765	2378	3104	3951	4924	6029	7272	8658	10194	11884
100.0	988	1460	2046	2756	3598	4579	5706	6987	8428	10035	11815	13774
160.0	1258	1857	2604	3508	4579	5827	7262	8892	10726	12771	15037	17529
300.0	1736	2564	3595	4842	6321	8045	10026	12276	14808	17631	20759	24200
400.0	2012	2972	4166	5612	7326	9324	11620	14228	17162	20435	24060	28048
500.0	2256	3332	4671	6293	8215	10455	13029	15954	19244	22914	26978	31450
750.0	2778	4103	5751	7748	10114	12872	16042	19642	23693	28211	33215	38721
1000.0	3220	4755	6666	8980	11722	14919	18593	22766	27461	32698	38497	44879
2000.0	4594	6785	9512	12814	16728	21289	26532	32487	39187	46660	59436	64042
3000.0	5656	8354	11711	15776	20596	26212	32666	39999	48247	57448	67638	78850
5000.0	7351	10856	15219	20502	26766	34064	42453	51982	62702	74660	87902	102473
7500.0	9050	13367	18739	25242	32953	41941	52268	64000	77199	91922	108226	126166
10,000.0	10489	15492	21718	29258	38195	48610	60580	74179	89475	106540	125436	146230
20,000.0	14968	22107	30992	41751	54505	69367	86449	105854	127683	152034	178900	208672
30,000.0	18429	27219	38158	51404	67107	85406	106437	130329	157206	187187	220388	256920
50,000.0	23950	32373	49590	66805	87212	110993	138325	169375	204304	243267	286415	333894
75,000.0	29487	43552	61056	82251	107376	136657	170308	208537	251542	299515	352639	411096
100,000.0	34177	50478	70765	95331	124452	158389	197392	241701	291544	347145	408718	476471

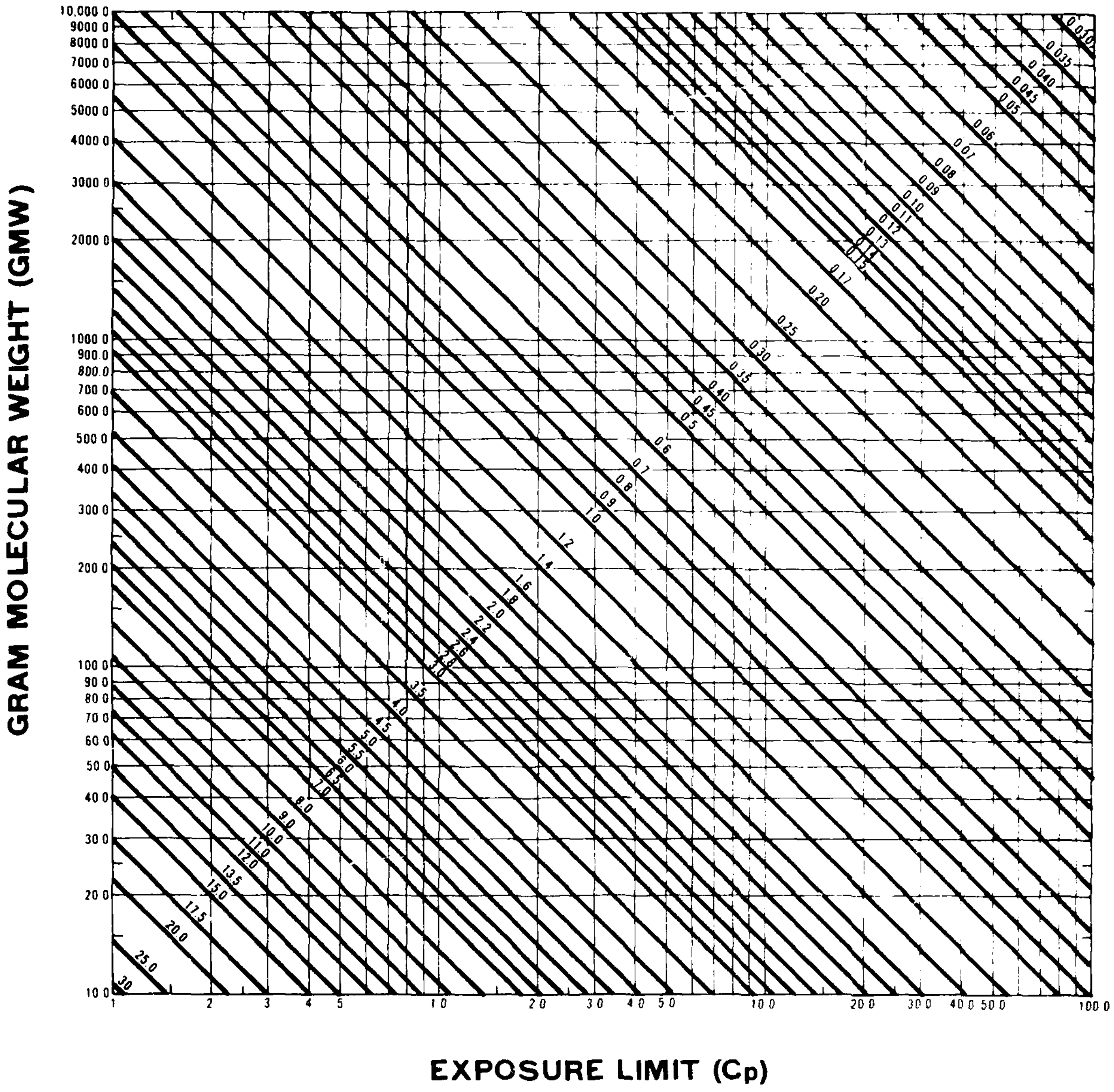


Figure 3. Nomogram for Determining Chemical Factors (CF). $CF = 30.476(Cp \cdot GMW)^{-0.513}$. The CF values are indicated by the diagonal lines as labeled.

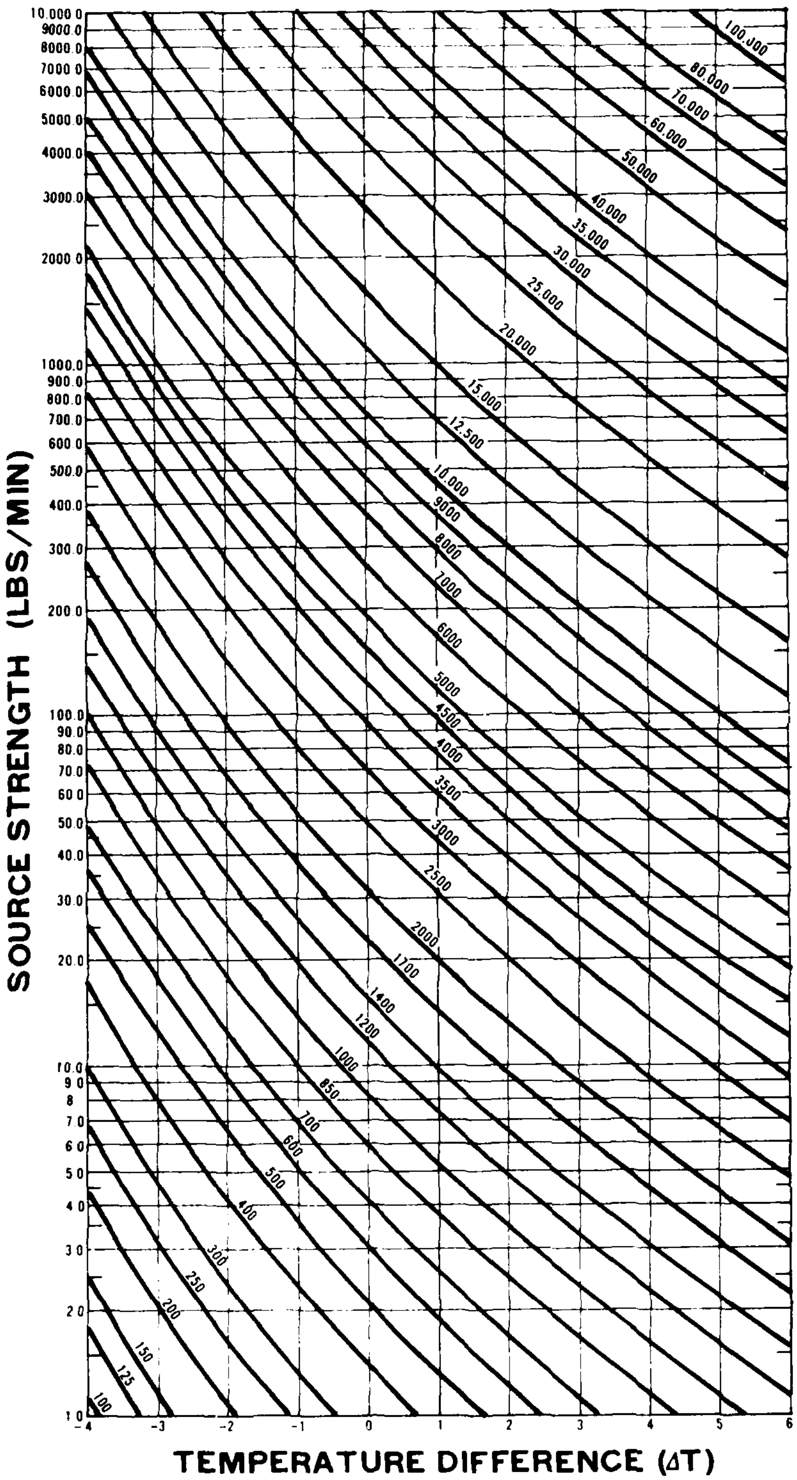


Figure 4. Nomogram for Determining Diffusion Factors (DF). $DF = Q^{0.513} (\Delta T + 10)^{2.53}$. The DF values are indicated by the curved diagonal lines as labeled.

Chapter 6

METHOD 3: UNIVERSAL NOMOGRAM

The steps to determine the dimensions of a toxic corridor using this method are presented below. A flow chart for using Method 3 is depicted in Figure 5. Where applicable, preferred and alternate approaches are given. The toxic corridor length nomogram, Figure 6, is required. Two copies of a suggested worksheet are provided in Appendix A; one with sample corridor calculations (Figure A-1) and one blank copy (Figure A-2).

a. STEP 1: Determine source strength (lb/min).

(1) Preferred. Obtain a source strength from the disaster response force (DRF). NOTE: Although weather personnel are not responsible for determining source strength, a toxic corridor length calculation cannot be made without it. Appendix C provides an equation for calculating evaporative source strengths based on the surface area covered by the toxic chemical spill. Use this Appendix to assist the agency responsible for estimating source strengths.

(2) Alternate. For small amounts of liquid or gas (less than 2000 lb), assume the worst case which is total release of the material in 1 minute. For large amounts of a gas (2000 lb or more), assume total release over 5 minutes. For large amounts of liquid, assume a source strength of 2000 lb per minute.

(3) Alternate. For releases of large amounts of material where a source strength cannot be determined from the above procedures, go to alternate procedure in Step 3.

b. STEP 2: Determine temperature difference (delta-T (^{o}F)).

(1) Preferred. Use the mean delta-T based on at least a 10-minute record from a 54-6 foot delta-T instrument. (Available at TITAN II missile sites. Refer to Appendix B, Figure B-1.) NOTE: 54-6 foot delta-T measurements can be made by using a sling psychrometer at the 54- and 6-foot levels of a radar tower.

(2) Alternate. Use mean surface wind speed category, solar elevation angle, and sky condition to obtain an estimated temperature difference from Table B-1, Appendix B. Refer to the notes in this table concerning rough terrain and forested regions prior to estimating the temperature difference.

c. STEP 3: Determine Toxic Corridor Length (TCL) in feet.

(1) Preferred

(a) Enter Part A of Figure 6 with source strength determined in Step 1 and project along the constant source strength line until the diagonal line representing the temperature difference value determined in Step 2 is intersected. From this point of intersection extend a line horizontally into Part B.

(b) Enter Part C with the appropriate exposure limit (Cp) provided by the Bioenvironmental Engineer (BEE), or taken from Table 33. Extend a horizontal line from this exposure limit until the diagonal line labeled with the approprate gram molecular weight (GMW) is intersected. The GMW for the toxic chemical of concern can be found in Table 33 or obtained from the BEE. From this intersection, project a line vertically into Part B.

(c) Read the toxic corridor length from the diagonal line at the point where the projections from Part A and Part C intersect in Part B.

(2) Alternate. For releases of a large amount of material where no source strength is available, use the distance the wind would carry the material in one hour. This is an interim forecast which must be updated when particulars are known.

d. STEP 4: Determine mean wind direction and wind direction variability, R (degrees of azimuth). If the surface wind is equal to or less than 3 knots, go to Step 6.

(1) Preferred. Use the 10-minute recorded wind direction trace and eliminate the two furthest direction fluctuations on each side of the mean. Variability, R, is the difference in degrees between the third largest fluctuation on each side of the mean direction.

(2) Alternate. Note the wind fluctuations indicated by an anemometer dial over a 2-minute period. Variability, R, is the difference in degrees between the largest fluctuation on each side of the mean direction.

(3) Approximate. If wind direction fluctuation information is unavailable, assume R is 60° when the wind speed is between 4 and 10 knots; assume R is 30° when the wind speed is greater than 10 knots.

e. STEP 5: Determine corridor width (W) in degrees by multiplying the value obtained for R in Step 4 by 1.5.

f. STEP 6: Plot the toxic corridor.

(1) Wind speed greater than 3 knots. Draw the corridor center line from the source to the point on the wind direction circle corresponding to the direction the mean wind is blowing towards (i.e., 180 degrees from the recorded mean wind direction), as determined in Step 4. Place W/2, calculated in Step 5, on each side of the center line. Draw the lines which define each side of the corridor. See example worksheet, Figure A-1 in Appendix A.

(2) Wind speed equal to or less than 3 knots. The corridor is a circle of radius equal to the corridor length determined in Step 3.

g. STEP 7: Trend forecast. If significant changes in wind direction are expected within the next hour or two, include this information in your briefing. A change in direction that would affect evacuation is considered significant. Based on continued close monitoring of weather conditions, relay any significant changes in the toxic corridor forecast to the DRF. Consider changes in winds that have occurred between the time of the spill and the time of the forecast. These changes could alter the shape and size of the toxic corridor.

TOXIC CORRIDOR CALCULATIONS
USING METHOD 3

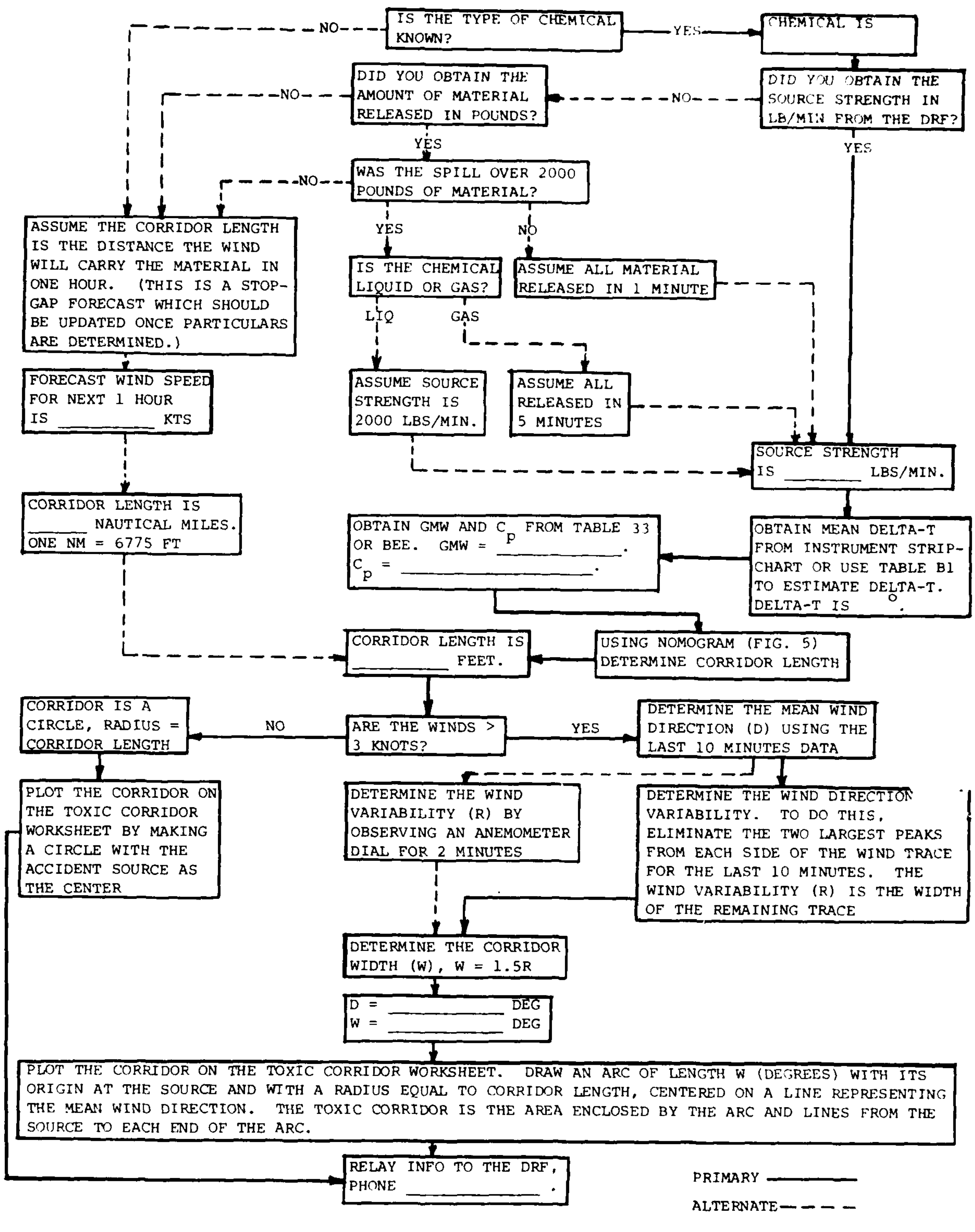


Figure 5. Flow Chart for Method 3.

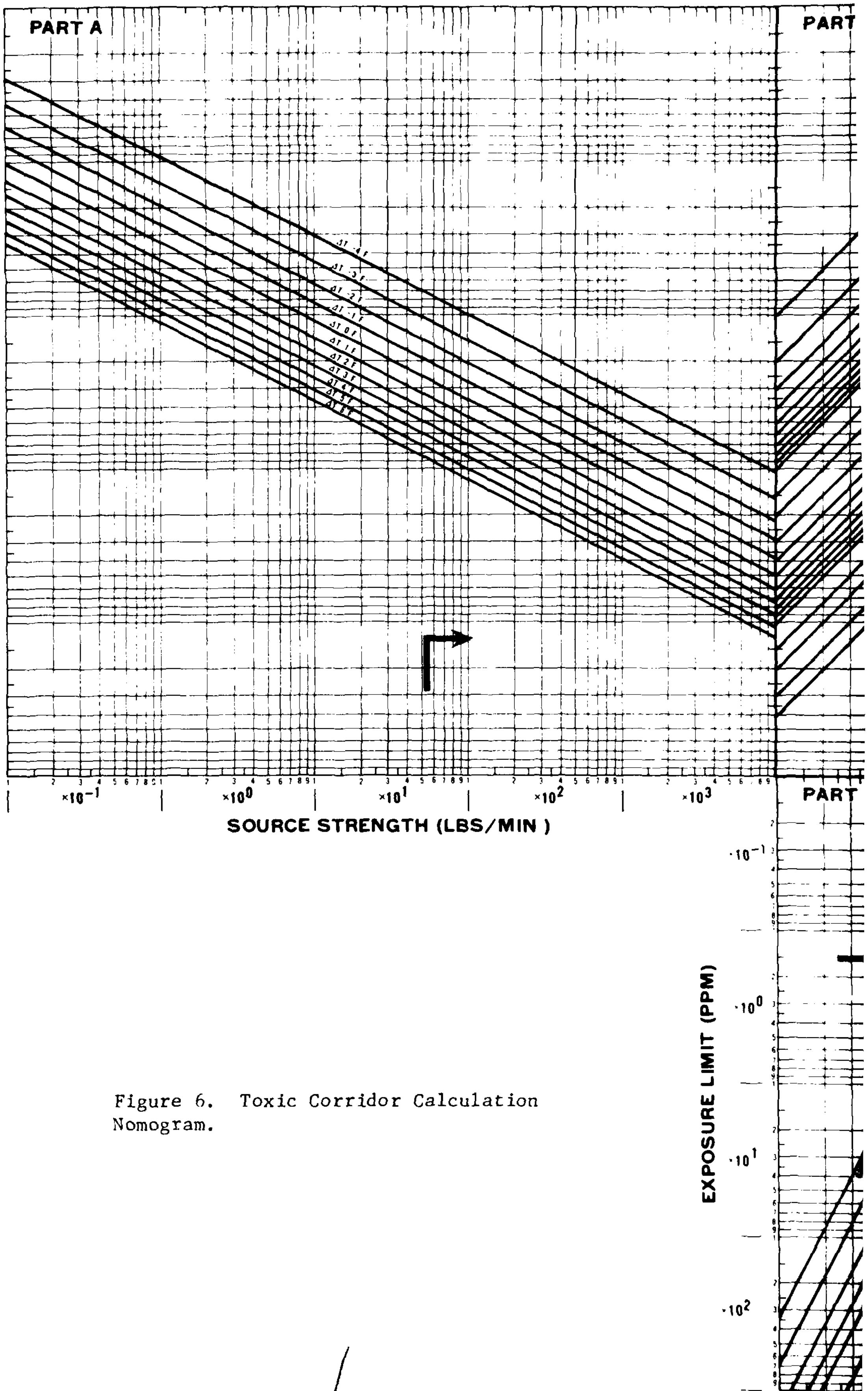
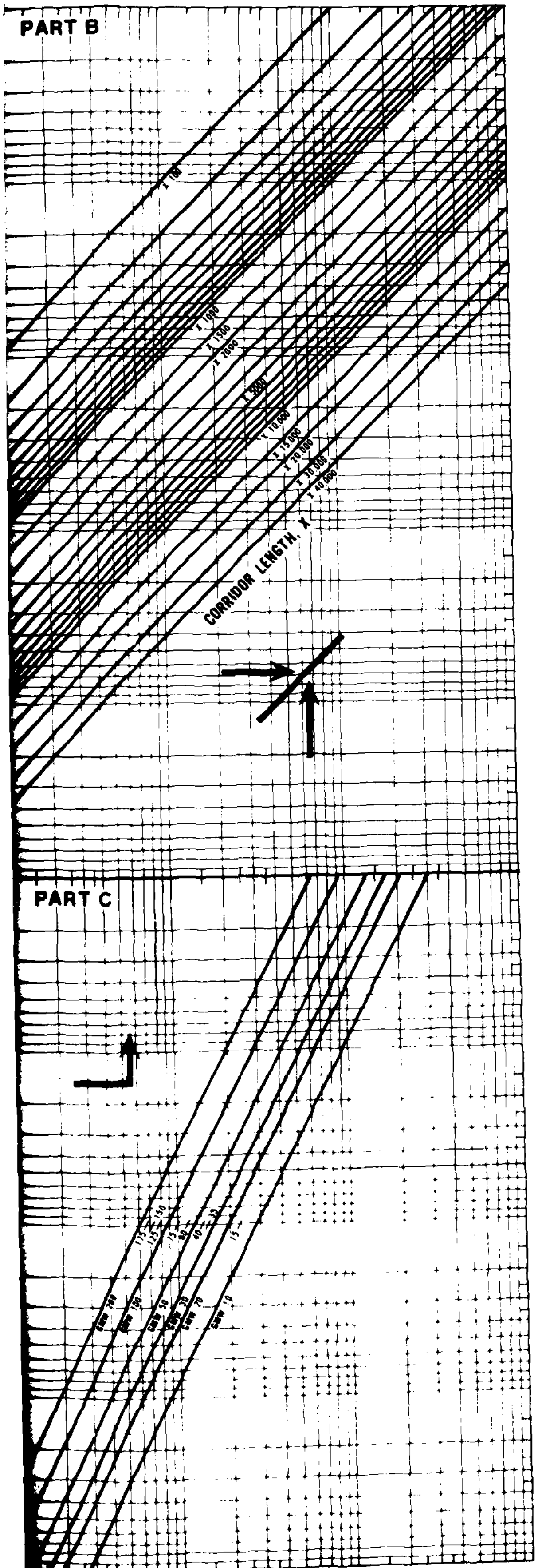


Figure 6. Toxic Corridor Calculation Nomogram.


PART B
CORRIDOR LENGTH, X
PART C

Chapter 7

METHOD 4: PROGRAMMABLE CALCULATOR

The steps to determine the dimensions of a toxic corridor using this method are presented below. Where applicable, preferred and alternate approaches are given. Input values pertaining to the toxic chemical of concern may be either found in Table 33 or requested from your local Bioenvironmental Engineer (BEE). Following the list of steps is a listing of a TI-59 Calculator Program*, sample input/output, and procedures for making the toxic corridor length calculation. Two copies of a suggested worksheet are provided in Appendix A; one with sample corridor calculations (Figure A-1) and one blank copy (Figure A-2). A flow chart for using Method 1 is depicted in Figure 7.

a. STEP 1: Determine source strength (lb/min).

(1) Preferred. Obtain a source strength from the disaster response force (DRF). NOTE: Although weather personnel are not responsible for determining source strength, a toxic corridor length calculation cannot be made without it. Appendix C provides an equation for calculating evaporative source strengths based on the surface area covered by the toxic chemical spill. Use this Appendix to assist the agency responsible for estimating source strengths.

(2) Alternate. For small amounts of liquid or gaseous material (less than 2000 lb), assume the worst case which is total release of the material in 1 minute. For large amounts of a gas (2000 lb or more), assume total release over 5 minutes. For large amounts of liquid, assume a source strength of 2000 lb per minute.

(3) Alternate. For releases of a large amount of material where a source strength cannot be determined from the above procedures, go to the alternate procedure in Step 4.

b. STEP 2: Determine temperature difference (delta-T (^{o}F)).

(1) Preferred. Use the mean delta-T based on at least a 10-minute record from a 54-6 foot delta-T instrument. (Available at TITAN II missile sites. Refer to Appendix B, Figure B-1.) NOTE: 54-6 foot delta-T measurements can be made by using a sling psychrometer at the 54- and 6-foot levels of a radar tower.

(2) Alternate. Use mean surface wind speed category, solar elevation angle, and sky condition to obtain an estimated temperature difference from Table B-1, Appendix B. Refer to the notes in this table concerning rough terrain and forested regions prior to estimating the temperature difference.

c. STEP 3: Determine the gram molecular weight (GMW) and the appropriate exposure limit (normally a 30-minute SPEL) for the particular toxic chemical of concern.

(1) Preferred. Use Table 33 for these data.

(2) Alternate. If the exposure limit or GMW for the toxic chemical is not listed in Table 33, request this information from your local BEE.

d. STEP 4: Determine toxic corridor length (TCL) in feet.

(1) Preferred. Follow the "TI-59 User Instructions" for calculating the toxic corridor length.

(2) Alternate. For releases of a large amount of material where no source strength is available, use the distance the wind would carry the material in one hour. This is an interim forecast which must be updated when particulars are known.

*NOTE: The TI-59 program presented in this report was provided by Maj Lomax, a Staffmet at Det 10, 2WS, Eglin AFB FL. A more specialized TI-59 program was provided to Air Weather Service/Aerospace Sciences by another Staffmet, Capt Dargitz from Det 30, 2WS, Vandenberg AFB CA. Although Capt Dargitz's program is tailored for liquid missile fuels and may be somewhat site-specific, his approach is unique and may be of interest to others with similar interests or concerns.

e. STEP 5: Determine mean wind direction and wind direction variability, R (degrees of azimuth). If the surface wind is equal to or less than 3 knots, go to Step 7.

(1) Preferred. Use the 10-minute recorded wind direction trace and eliminate the two furthest direction fluctuations on each side of the mean. Variability, R, is the difference in degrees between the third largest fluctuation on each side of the mean direction.

(2) Alternate. Note the wind fluctuations indicated by an anemometer dial over a 2-minute period. Variability, R, is the difference in degrees between the largest fluctuation on each side of the mean direction.

(3) Approximate. If wind direction fluctuation information is unavailabe assume R is 60° when the wind speed is between 4 and 10 knots; assume R is 30° when the wind speed is greater than 10 knots.

f. STEP 6: Determine corridor width (W) in degrees by multiplying the value obtained for R in Step 5 by 1.5.

g. STEP 7: Plot the toxic corridor.

(1) Wind speed greater than 3 knots. Draw the corridor center line from the source to the point on the wind direction circle corresponding to the direction the mean wind is blowing towards (i.e., 180 degrees from the recorded mean wind direction), as determined in Step 5. Place W/2, calculated in Step 6, on each side of the center line. Draw the lines which define each side of the corridor. See example worksheet, Figure A-1 in Appendix A.

(2) Wind speed equal to or less than 3 knots. The corridor is a circle of radius equal to the corridor length determined in Step 4.

h. STEP 8: Trend forecast. If significant changes in wind direction are expected within the next hour or two, include this information in your briefing. A change in direction that would affect evacuation is considered sigificant. Based on continued close monitoring of weather conditions, relay any significant changes in the toxic corridor forecast to the DRF. Consider changes in winds that have occurred between the time of the spill and the time of the forecast. These changes could alter the shape and size of the toxic corridor.

TI-59 User Instructions

This program may be used with or without the printer. It defaults to the 90-percent corridor length nonexceedence probability (Pr). This is the probability that the specified exposure limit will not be exceeded beyond the calculated corridor distance. This probability may be changed by changing the Percent Parameter (PPAR) which is the same as the probability factor (P) in the Ocean Breeze and Dry Gulch equation (see Glossary). The probability factors for specified nonexceedence probabilties are listed in Table 35. Once the PPAR is changed, it will remain at the new value until it is changed again or the program is reentered.

Table 35. Probability Factors (Miller and Miller, 1964).

Probability of Not Being Exceeded	Distance Probability Factor (P)
0.97	2.04
0.95	1.87
0.90	1.63
0.85	1.48
0.80	1.38
0.75	1.30
0.50	1.00
0.25	0.770
0.20	0.726
0.15	0.674
0.10	0.614
0.05	0.535

The procedures for entering the calculator program and calculating corridor lengths are listed below:

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1.	Turn on calculator (and printer)		CLR	
2.	Slide side one (1) into the lower slot			1.
3.			CLR	
4.	Turn card around and enter side three (3)			3.
5.	(Optional) Enter new PPAR	PPAR	A'	1532312124
6.	Enter gram molecular weight of chemical	GMW	A	GMW
7.	Enter exposure limit in PPM	PPM	B	PPM
8.	Enter source strength in lbs/min (Q)	Q	C	Q
9.	Enter delta-T value	DL-T	D	DL-T
10.	Compute corridor length (L)	No Entry	E	L in feet

Any of the entered parameters may be changed by reentering the new value, pressing the appropriate key (A-D), and then pressing E for the new corridor length.

The following sample input/output is useful for checking the program after it has been entered into the calculator memory.

32.05 GMW
20. PPM
40. Q
-2. DL-T

CORRIDOR LENGTH
1414.869997 FEET
.2679678025 S. MI
.2328576534 N. MI
431.2523751 M
.4312523751 KM.

Sample Input/output

Default value of P=1.63 for probability of 90 percent that the calculated toxic corridor length will not be exceeded.

2.04 PPAR
CORRIDOR LENGTH
1770.757542 FEET
.3353707466 S. MI
.2914292104 N. MI
539.7268989 M.
.5397268989 KM.

Sample Input/output

Value of P altered from default value to 2.04 giving a probability of 97 percent that corridor length will not be exceeded.

The TI-59 program for calculating toxic corridor length is listed below.

TI-59 PROGRAM LISTING
BANK 1

STEP NO.	KEY PRESSED	KEY SYMBOL	STEP NO.	KEY PRESSED	KEY SYMBOL	STEP NO.	KEY PRESSED	KEY SYMBOL
000	76	LBL	052	42	STO	104	43	RCL
001	10	E'	053	39	39	105	23	23
002	69	OP	054	05	5	106	55	÷
003	00	00	055	09	9	107	43	RCL
004	92	RTN	056	71	SBR	108	21	21
005	76	LBL	057	23	LNX	109	55	÷
006	19	D'	058	91	R/S	110	43	RCL
007	42	STO	059	76	LBL	111	22	22
008	09	09	060	11	A	112	54	)
009	73	RC*	061	42	STO	113	45	Y^X
010	09	09	062	21	21	114	43	RCL
011	76	LBL	063	04	4	115	35	35
012	18	C'	064	01	1	116	65	X
013	69	OP	065	71	SBR	117	53	(
014	04	04	066	23	LNX	118	43	RCL
015	92	RTN	067	91	R/S	119	24	24
016	76	LBL	068	76	LBL	120	85	+
017	17	B'	069	12	B	121	01	1
018	42	STO	070	42	STO	122	00	0
019	08	08	071	22	22	123	54	)
020	04	4	072	04	4	124	45	Y^X
021	42	STO	073	02	2	125	43	RCL
022	09	09	074	61	GTO	126	37	37
023	76	LBL	075	23	LNX	127	95	=
024	22	INV	076	76	LBL	128	42	STO
025	73	RC*	077	13	C	129	25	25
026	08	08	078	42	STO	130	36	PGM
027	84	OP*	079	23	23	131	24	24
028	09	09	080	04	4	132	12	B
029	69	OP	081	03	3	133	42	STO
030	38	38	082	61	GTO	134	28	28
031	97	DSZ	083	23	LNX	135	55	÷
032	09	09	084	76	LBL	136	43	RCL
033	22	INV	085	14	D	137	50	50
034	69	OP	086	42	STO	138	95	=
035	05	05	087	24	24	139	42	STO
036	92	RTN	088	04	4	140	29	29
037	76	LBL	089	04	4	141	36	PGM
038	23	LNX	090	61	GTO	142	24	24
039	19	D'	091	23	LNX	143	19	D'
040	02	2	092	76	LBL	144	42	STO
041	00	0	093	15	E	145	26	26
042	22	INV	094	43	RCL	146	36	PGM
043	44	SUM	095	39	39	147	24	24
044	09	09	096	65	X	148	15	E
045	73	RC*	097	43	RCL	149	42	STO
046	09	09	098	34	34	150	27	27
047	69	OP	099	65	X	151	05	5
048	06	06	100	53	(	152	04	4
049	92	RTN	101	43	RCL	153	17	B'
050	76	LBL	102	36	36	154	05	5
051	16	A'	103	65	X	155	42	STO

Bank 2

STEP NO.	KEY PRESSED	KEY SYMBOL	STEP NO.	KEY PRESSED	KEY SYMBOL
156	07	07	166	02	2
157	04	4	167	01	1
158	05	5	168	95	1
159	76	LBL	169	97	=
160	24	CE	170	07	07
161	71	SBR	171	24	CE
162	23	LNX	172	95	ADV
163	43	RCL	173	43	RCL
164	09	09	174	25	25
165	85	+	175	91	R/S

BANK 3

STORED VALUE	LOCATION
0.	30
0.	31
0.	32
0.	33
3.28	34
0.513	35
29.75	36
2.53	37
0.	38
1.63	39
0.	40
22304300.	41
33333000.	42
34000000.	43
16272037	44
21171737.	45
36403024.	46
31403024.	47
30400000.	48
26304000.	49
1000.	50
153235.	51
3524163235.	52
27173122.	53
3723000000.	54
1532312124.	55
1617311517.	56
24313717.	57
3542132740	58
33331335.	59

LABELS

STEP NO.	KEY PRESSED	KEY SYMBOL
001	10	E'
006	19	D'
012	18	C'
017	17	B'
024	22	INV
038	23	LNX
051	16	A'
098	11	A
107	12	B
115	13	C
123	14	D
131	15	E
198	23	CE

TOXIC CORRIDOR CALCULATIONS
USING METHOD 4

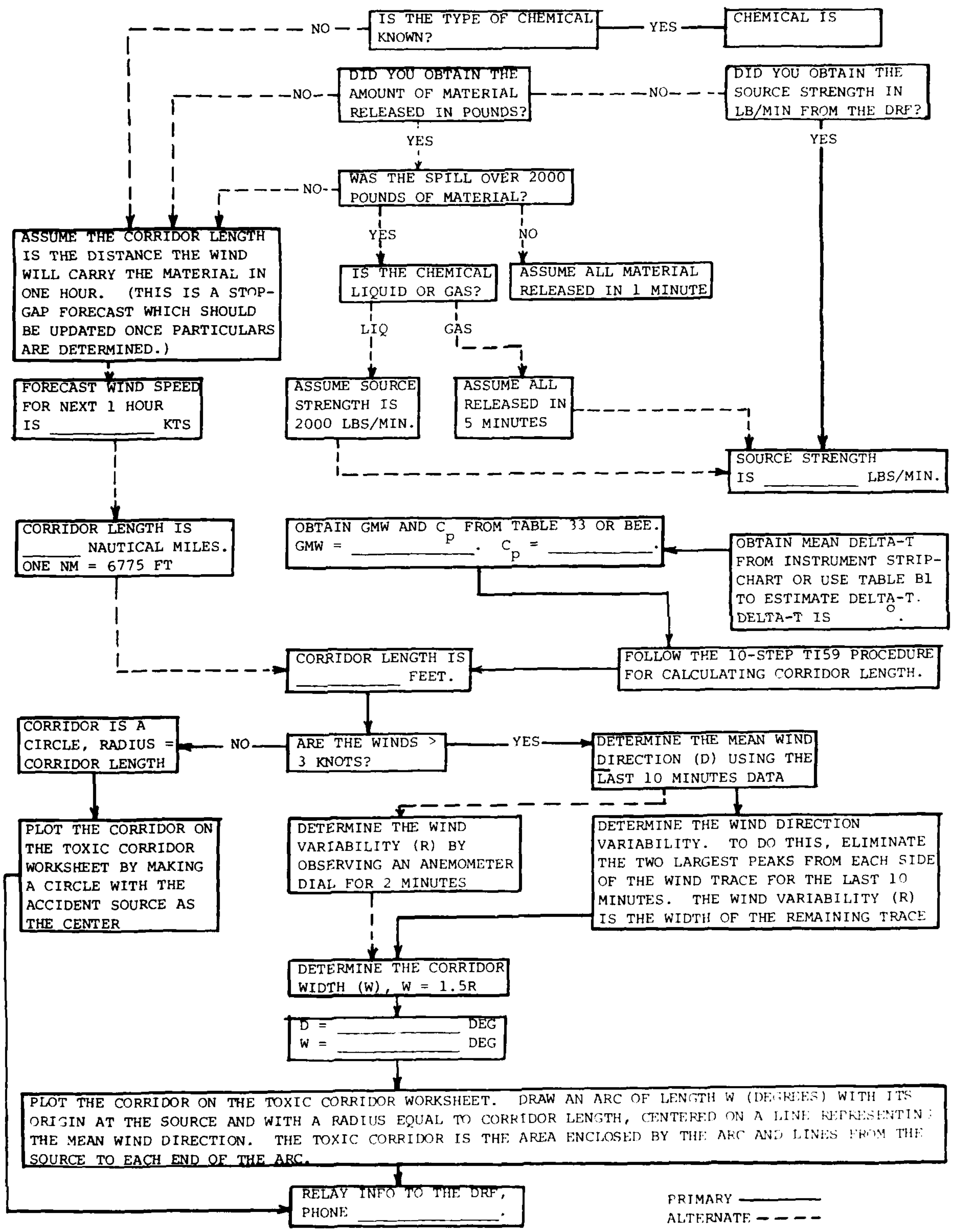


Figure 7. Flow Chart for Method 4.

Chapter 8

SUMMARY

Toxic chemicals are routinely shipped by rail, barge, and truck within and near populated areas. They are stored at Department of Defense (DOD) installations and in the surrounding civilian communities and are used in many tasks. Movement, use, and storage of these chemicals creates the risk of accidental spills or releases of these chemicals to the atmosphere. When this happens, they could rapidly become a health hazard.

This report has presented four methods based upon the Ocean Breeze and Dry Gulch equation that can be used by weather forecasters in producing rapid estimates of the diffusion of these toxic chemicals. The end product is a toxic corridor forecast for which there is a 90-percent probability that toxic chemical concentrations exceeding a specified value will be contained within the corridor. This concentration level will normally be a Short-Term Public Emergency Limit established by the Committee on Toxicology of the National Academy of Sciences (1979).

The four approaches for producing toxic corridor length forecasts are:

a. Use toxic corridor tables to estimate the corridor length based on a delta-T value and a source strength. Each chemical requires a separate table.

b. Use a table and graph to separate the diffusion equation into a diffusion factor and a chemical factor. The corridor length is the product of this pair of factors.

c. Use a nomogram to calculate corridor length based on the gram molecular weight of the chemical, source strength, exposure limit, and delta-T.

d. Use a programmable calculator to calculate corridor length.

The procedure for estimating the corridor width is the same in each approach. Step-by-step instructions direct the forecaster in producing the forecasts. A complete, separate set of instructions for each of the four approaches (called methods 1, 2, 3, and 4) is included. Table 36 summarizes the four methods. Additional information is provided in the appendixes to this report.

The toxic corridor forecast produced by each of these techniques is an approximate solution subject to several errors. These errors include:

a. Errors caused by an error in the measurement of delta-T.

b. Errors caused by an error in estimating source strength.

c. Terrain-induced errors that alter the diffusion characteristics of the atmosphere.

In general, this report is intended to aid the forecaster by allowing flexibility in producing toxic corridor diffusion forecasts.

Table 36. Summary of Four Toxic Corridor Methods.

METHOD	PROCEDURE	MATERIALS REQUIRED	DATA REQUIRED	LIMITATIONS
1	1. Estimate toxic corridor length (TCL) from toxic corridor length tables. 2. Calculate toxic corridor width (W) from wind direction variability (R). 3. Plot toxic corridor.	1. Toxic corridor length tables (Tables 2-32). 2. Toxic corridor worksheet (optional).	1. Source strength (Q, lb/min) from Disaster Response Force (DRF) and Appendix C 2. 54-6 foot temperature difference (delta-T, ^{o}F) 3. Mean wind direction (^{o}) 4. Wind direction variability (R, degrees) 5. Wind speed (knots)	1. A 1^{o}F error in delta-T can cause an error in toxic corridor length (TCL) as large as 40 percent (see Appendix D). 2. Errors in Q of ±20 percent can cause errors of ±10 percent in TCL (see Appendix C). 3. Terrain and surface roughness can affect atmospheric dispersion and wind direction and speed (see Table B-1). 4. Meteorological elements are assumed to be homogeneous in horizontal.
2	1. Separate diffusion equation into diffusion factor (DF) and chemical factor (CF) using tables and graphs. 2. Calculate toxic corridor length (TCL) from product of DF and CF. 3. Calculate toxic corridor width (W) from wind direction variability (R). 4. Plot toxic corridor.	1. Table of Chemical Factors (Table 33), or Nomogram for Determining Chemical Factors (Figure 3). 2. Table of Diffusion Factors (Table 34) or Nomogram for Determining Diffusion Factors (Figure 4). 3. Toxic corridor worksheet (optional).	1. Source strength (Q, lb/min) 2. 54-6 foot temperature difference (delta-T, ^{o}F) 3. Exposure limit (C_p) 4. Gram molecular weight (GMW) of chemical 5. Mean wind direction (^{o}) 6. Wind direction variability (R, degrees) 7. Wind speed (knots)	
3	1. Obtain toxic corridor length (TCL) from universal nomogram. 2. Calculate toxic corridor width (W) from wind direction variability (R). 3. Plot toxic corridor.	1. Universal nomogram (Figure 6). 2. Toxic corridor worksheet (optional).	1. Source strength (Q, lb/min) 2. 54-6 foot temperature difference (delta-T, ^{o}F) 3. Exposure limit (C_p) 4. Gram molecular weight (GMW) of chemical 5. Mean wind direction (^{o}) 6. Wind direction variability (R, degrees) 7. Wind speed (knots)	
4	1. Calculate toxic corridor length (TCL) using TI-59 programmable calculator with TCL program. 2. Calculate toxic corridor width (W) from wind direction variability (R). 3. Plot coxic corridor.	1. TI-59 programmable calculator. 2. Toxic corridor length program card. 3. Toxic corridor worksheet (optional).	1. Source strength (Q, lb/min) 2. 54-6 foot temperature difference (delta-T, ^{o}F) 3. Exposure limit (C_p) 4. Gram molecular weight (GMW) of chemical 5. Mean wind direction (^{o}) 6. Wind direction variability (R, degrees) 7. Wind speed (knots)	

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Appendix A

TOXIC CORRIDOR WORKSHEET

WORKSHEET WITH EXAMPLE

Name of Chemical ___Aerozine 50___

1. Source strength ___40___ lbs/min (from environmental health service, disaster response force, or estimated)

2. 54-6 foot delta-T ___-2___ ^{o}F (from instrument or table)

3. Toxic Corridor length ___1415___ feet (from toxic corridor table)

4. Mean surface wind ___290°/4 kt___; wind variability (R) ___40___ degrees (from wind trace, instrument dial, or estimated)

5. Corridor width (W) ___60___ degrees (W = 1.5R)

6. Toxic corridor plot

7. Surface wind trend forecast (no change/change to °/ kt)

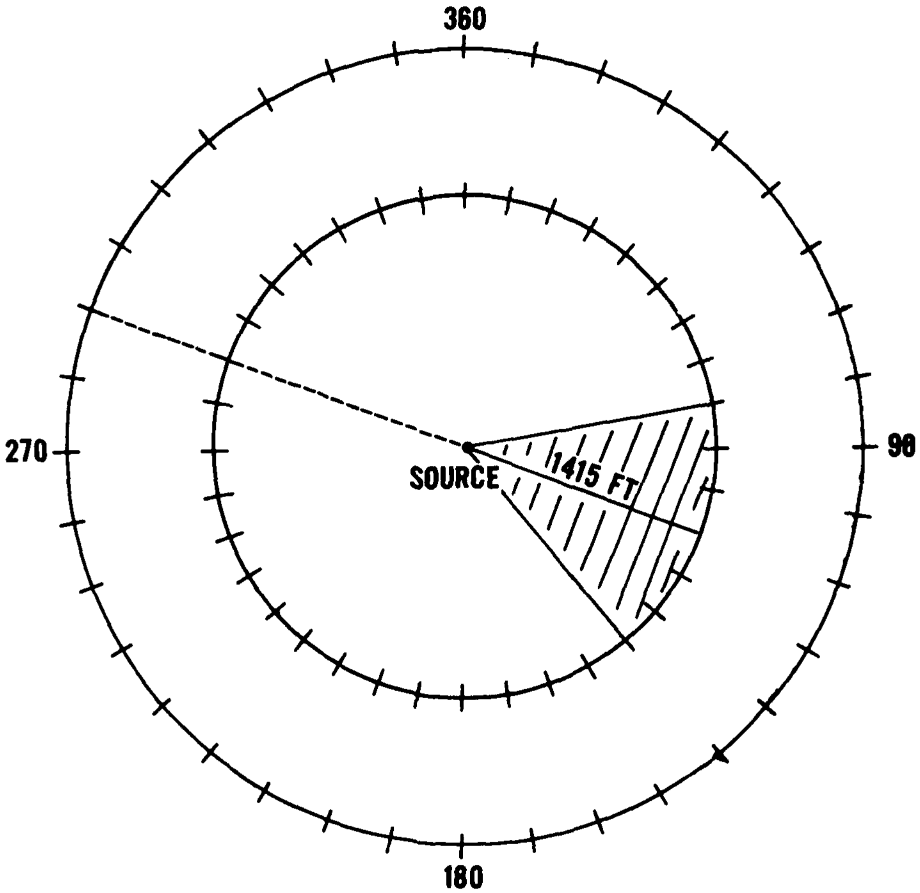


Figure A-1. Toxic Corridor Forecast Worksheet with Example Calculations.

TOXIC CORRIDOR WORKSHEET

Name of Chemical ____________________

1. Source strength ________________lbs/min (from environmental health service, disaster response force, or estimated)

2. 54-6 foot delta-T __________°F (from instrument or table)

3. Toxic Corridor length ___________feet (from toxic corridor table)

4. Mean surface wind ____________________; wind variability (R) _____________ degrees (from wind trace, instrument dial, or estimated)

5. Corridor width (W) _________ degrees (W = 1.5R)

6. Toxic corridor plot

7. Surface wind trend forecast no change/change to °/ kt)

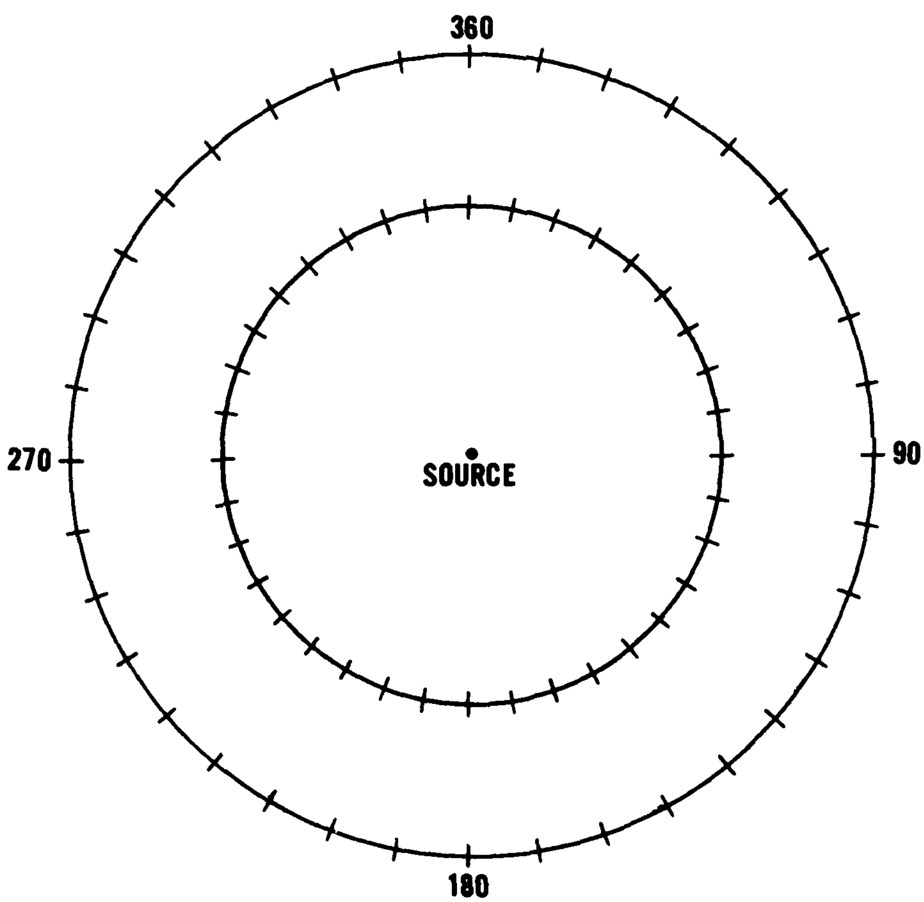


Figure A-2. Toxic Corridor Forecast Worksheet.

Appendix B

PROCEDURES FOR DETERMINING METEOROLOGICAL ELEMENTS

The mean 10-minute wind speed or direction is determined directly from the chart trace by adjusting the position of a straightedge held parallel to the chart edge, until there is an equal amount of the trace on both sides of the straightedge. The mean wind speed or direciton is the value intersected by the straightedge. Direction should be rounded to the nearest 5° and speed to the nearest 1 knot.

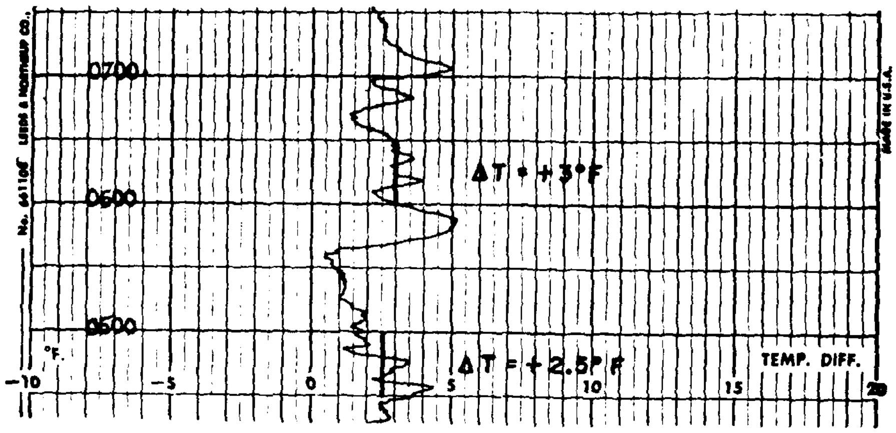
Where delta-T instrumentation is available, the mean 10-minute delta-T (54-6 ft) for a particular time period is determined in exactly the same manner given above, using the strip chart recording of delta-T instead of the wind record.

The range of the wind direction fluctuation (R) is obtained by subtracting the two largest fluctuation "peaks" from each side of the wind direction trace and measuring the width in degrees of the remaining trace. This can be done by moving a straightedge, held parallel to the chart edge, toward the center of the trace. After three peaks show, read the direction and round to the nearest 5°. Repeat the operation for the other side of the trace and record the difference in degrees between the two readings.

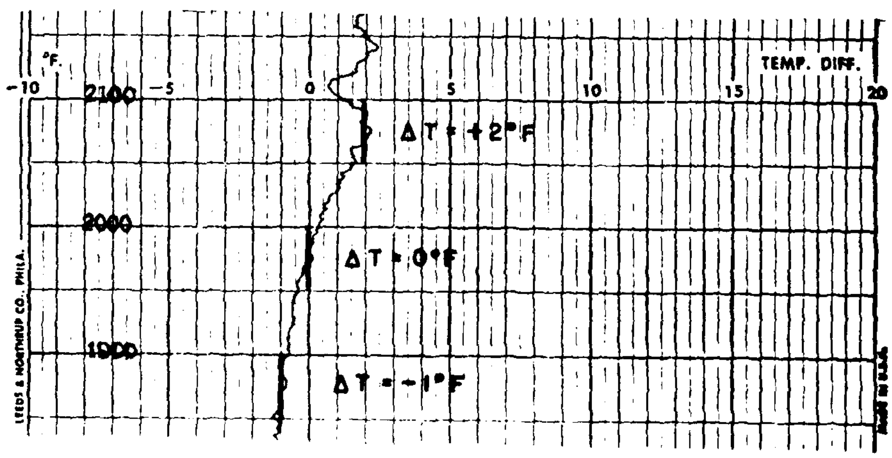
When the wind direction is oscillating about North, first one pen will trace and then the other, resulting in a trace on both sides of the chart. The method for computing R with such a trace is essentially the same as given above except that the straightedge is moved from the center of the chart outward toward each edge and the difference in readings should be subtracted from 360° to get the width of the trace. Several sample traces illustrating the procedures for obtaining the meteorological elements are given in Figures B-1 and B-2 extracted from AWSTR 176 "Diffusion Forecasting for TITAN II Operations" (Miller and Miller, 1964). Note that these examples are for a 30-minute time interval.

Table B-1 should be used to estimate temperature difference, 54-6 foot delta-T, if instrumental data are not available. An example is included in the table. Pay special attention to the notes concerning rough and forested terrain.

TEMPERATURE DIFFERENCE (54-6)



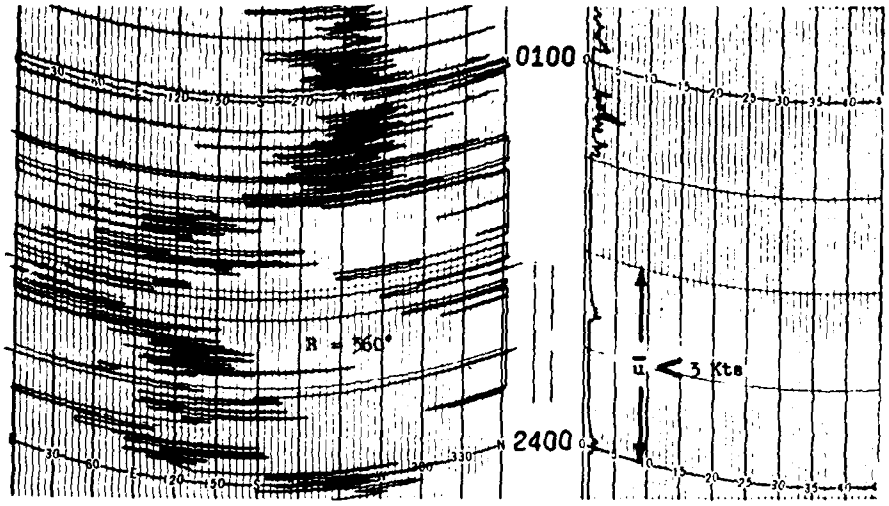
(a)



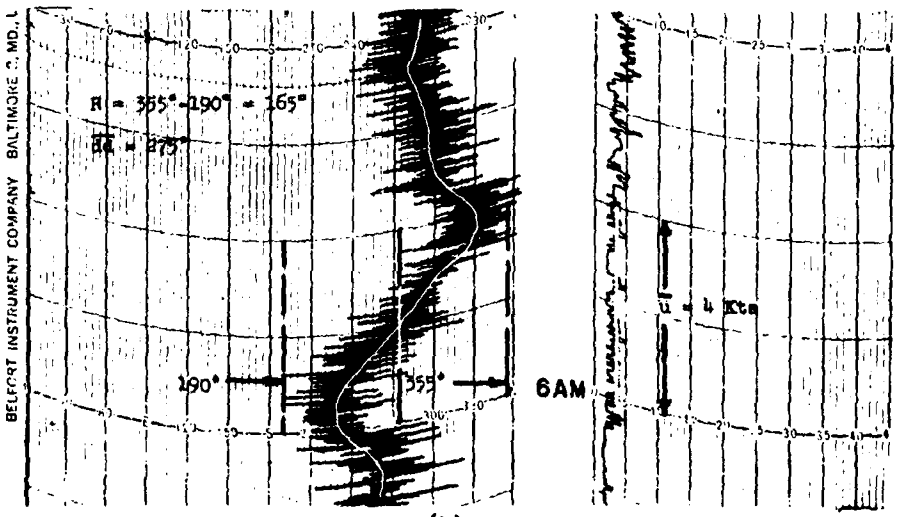
(b)

Figure B-1. Sample Traces of Temperature/Difference (ΔT).

WIND SPEED AND DIRECTION (12')



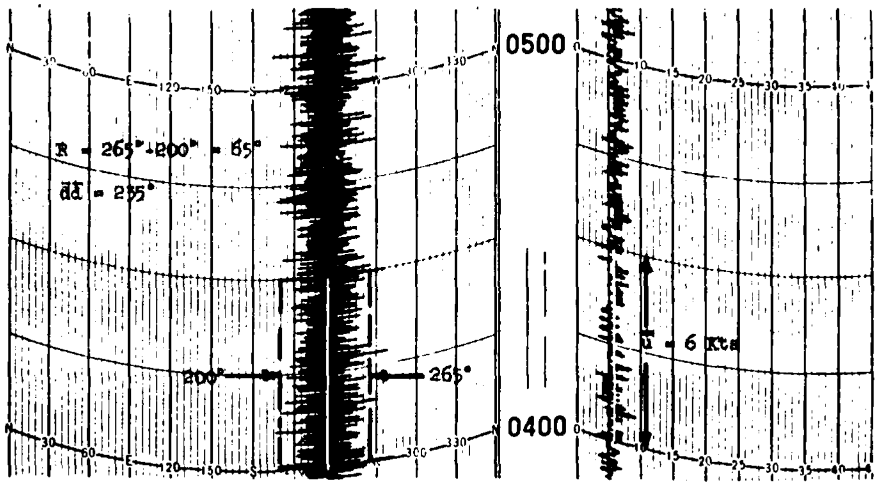
(a)



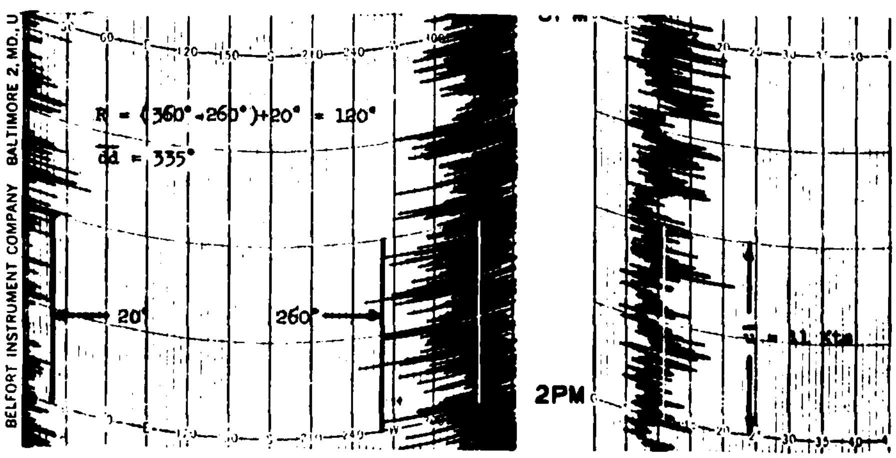
(b)

Figure B-2. Sample Traces of Wind Direction and Speed.

WIND SPEED AND DIRECTION (12')



(c)



(d)

Figure B-2 (cont'd). Sample Traces of Wind Direction and Speed.

Table B-1. Estimation of Temperature Difference, ^{o}F (54-6 ft ΔT). Before using this table refer to notes and example.

DAY — INCOMING SOLAR RADIATION (SOLAR ELEVATION ANGLE) / NIGHT

SURFACE WIND SPEED (kt)	DAY: STRONG (≥ 60)	DAY: MODERATE (36-60°)	DAY: WEAK (16-35°)	DAY: SUNRISE/SUNSET (≤ 15°)	NIGHT: CLEAR, SNOW	NIGHT: CLEAR, NO SNOW	NIGHT: CLOUD COVER 1/8-3/8, SNOW	NIGHT: CLOUD COVER 1/8-3/8, NO SNOW	NIGHT: CLOUD COVER 4/8-8/8, SNOW	NIGHT: CLOUD COVER 4/8-8/8, NO SNOW
	CLEAR SKY OR SCATTERED CLOUDS									
≤ 3	-2	-1	-1	0	6	5	5	4	4	3
4-6	-3	-2	-2	0	6	5	5	4	4	3
7-10	-3	-2	-1	0	5	4	4	3	3	2
≥ 11	-2	-1	-1	0	5	4	4	3	2	1

DAY — BROKEN CLOUDS ABV 7000 FT - A (>); EQUAL TO & BLO 7000 FT - B (≤)

SURFACE WIND SPEED (kt)	STRONG A	STRONG B	MODERATE A	MODERATE B	WEAK A	WEAK B	SUNRISE/SUNSET A	SUNRISE/SUNSET B
≤ 3	-1	-1	-1	-1	-1	0	0	0
4-6	-2	-2	-2	-2	-2	0	0	0
7-10	-2	-1	-1	-1	-1	0	0	0
≥ 11	-1	-1	-1	-1	-1	0	0	0

DAY — OVERCAST CLOUDS

SURFACE WIND SPEED (kt)	STRONG A	STRONG B	MODERATE A	MODERATE B	WEAK A	WEAK B	SUNRISE/SUNSET A	SUNRISE/SUNSET B
≤ 3	-1	0	-1	0	-1	0	0	0
4-6	-2	0	-2	0	-2	0	0	0
7-10	-1	0	-1	0	-1	0	0	0
≥ 11	-1	0	-1	0	-1	0	0	0

Note 1. Use sunrise/sunset category during the period from one hour before to one hour after sunrise/sunset.

Note 2. In rough terrain add (-1) to the number determined.

Note 3. If the toxic corridor is in a forest, use the next lower wind speed category than normal (unless the wind measurement is from within the forest canopy) and add (-1) to the resulting delta-T value. Do not use a delta-T more negative than (-4).

Note 4. Major Robert G. Curry developed this table while assigned to 3WW/DN. It originally appeared in 3WWP 105-13 and more recently in AWSP 105-57.

Example: It is a sunny day with scattered middle clouds. The surface wind speed is five knots, and the approximate solar elevation is 40 degrees. Calculate the temperature difference. Enter the day side of the table at proper windspeed and solar elevation angle. The answer is a temperature difference of (-2).

Appendix C

TOXIC CHEMICAL SOURCE STRENGTH DETERMINATION

The determination of toxic chemical source strengths is not the responsibility of weather personnel. Unfortunately, a toxic corridor cannot be determined without this input. Accurate toxic corridor forecasts require that reasonably accurate parameters, such as source strength, be used as inputs upon which the calculation can be based. A source strength estimate that is an order of magnitude too small (i.e., 10 percent of the true value) will result in a Toxic Corridor Length (TCL) estimate that is approximately 30 percent of that resulting from the proper source strength input. A source strength estimate that is 75 percent of its true value will result in a TCL that is 86 percent of that resulting from the true input. Figure C-1 displays the relationship between erroneous source strength inputs and TCL errors.

Figure C-1 illustrates that corridor lengths will be within ± 10 percent of "true" as long as source strengths are within ± 20 percent of "true." Estimating source strengths resulting from spills of toxic chemicals is always an extremely difficult task. Virtually every spill incident presents a completely new set of conditions under which the source strengths must be determined. Because of the difficulty encountered in making these estimates, the Air Force Engineering and Services Center has studied the problem, and the equation shown below was one result of their studies (Clewell, 1980 and Ille, 1978).

$$Q = 0.08V^{3/4} A (1 + 4.3 \times 10^{-3} T_p^2) Z \qquad \text{(C-1)}$$

where Q = source strength in kg/hr

V = wind speed in m/s

A = spill area in m^2

T_p = toxic chemical pool temperature in degrees Celsius

Z = dimensionless factor that depends upon the toxic chemical under consideration.

The factor Z is calculated from molecular weights and vapor pressures of the toxic chemicals of concern. The equation for Z is

$$Z = \frac{P_{v_b} \; GMW_b}{P_{v_h} \; GMW_h}$$

where P_v is vapor pressure (subscripts b and h represent the toxic chemical of concern and hydrazine, respectively), and GMW is the gram molecular weight for the chemical of concern (subscript b) and for hydrazine (subscript h).

The source strength equation was developed in terms of hydrazine where Z represents a factor to be used in converting the equation for use with other toxic chemicals. It should be apparent that Z equals 1 when a source strength for hydrazine is required.

Except for temperature, which remains in degrees Celsisus, the above equation has been converted to its equivalent in terms of English units. This was done to maintain a consistency of units throughout this report. The equation in terms of source strength in lb/min, with wind speed in knots, spill area in square feet, and pool temperature in degrees Celsius is

$$Q = 1.66 \times 10^{-4} V^{3/4} A (1 + 4.3 \times 10^{-3} T_p^2) Z$$

Table C-1 contains vapor pressures, gram molecular weights, and Z factors for a number of toxic chemicals.

REFERENCES

Clewell, Harvey J. III (Capt, USAF): "Estimation of Hazard Corridors for Toxic Liquid Spills." Paper presented at 1980 JANNAF Propulsion Meeting - Safety and Environmental Protection Specialist Session, Monterey, CA on 12 March 1980. (Based upon work performed at the Engineering and Services Laboratory, AF Engineering and Services Center, Tyndall AFB FL 32403.)

Ille, Gerhard and Charles Springer: "The Evaporation and Dispersion of Hydrazine Propellants from Ground Spills." CEEDO-TR-78-30, Civil and Environmental Engineering Development Office (presently the AF Engineering and Services Center), Tyndall AFB FL 32403 (August 1978).

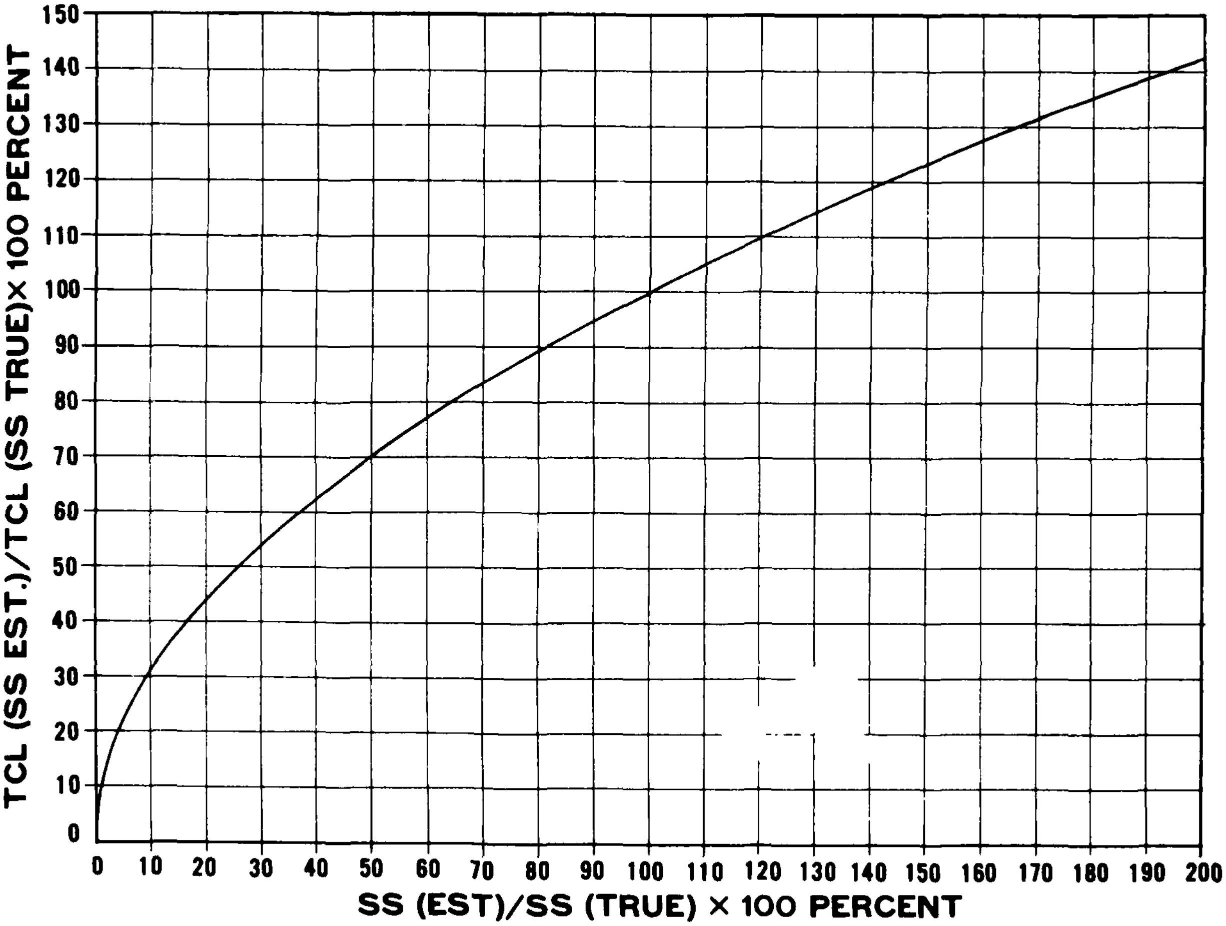


Figure C-1. Toxic Corridor Length Errors Resulting from Source Strength Estimation Errors.

Table C-1. Source Strength Factors (Z), GMW, and Vapor Pressures for Selected Toxic Chemicals.

TOXIC CHEMICAL	VAPOR PRESSURE				GMW	FORMULA	Z FACTOR	REMARKS
	psi	mb	in Hg	at temp °F				
Aerozine 50 (50% Hydrazine/50% UDMH)	3.1	213.7	6.3	80	53.0	$N_2H_4/(CH_3)_2$	16.5	Mixed 50/50%
Anhydrous Ammonia	158.17	10,902	321.9	80	17.031	NH_3	270.7	
Aniline	0.027	1.861	0.555	80	93.129	$C_6H_5NH_2$	0.253	
Bromine Pentafluoride	8.487	584.97	17.27	80	174,896	BrF_5	149.2	
Carbon Disulfide	6.987	481.60	14.22	80	76.139	CS_2	53.5	
Carbon Monoxide					28.011	CO		
Chlorine	115.383	7,952.8	234.85	80	70.906	Cl_2	822.3	
Chlorine Pentafluoride	58.76	4,050.043	1 9.599	77	130.445	ClF_5	770.4	
Chlorine Trifluoride	26.6	1,833.410	54.141	80	92.448	ClF_3	247.2	
Diborane					16.859	B_2H_6		
Ethylene Oxide	27.0	1,860.98	54.96	80	44.054	C_2H_4O	119.6	
Fluorine					37.997	F_2		
FLOX					33.798	F_2/O_2		Mixed 30/70%
Fuming Nitric Acid-Types I & IA	1.21	83.4	2.46	77	63.013	HNO_3	7.7	WFNA/IWFNA
Fuming Nitric Acid - Types III,IIIA, IIIB	2.7	186.1	5.5	77	63.013	HNO_3	17.1	RFNA/IRFNA
Hydrazine	0.31	21.4	0.63	80	32.045	N_2H_4	1	
H-70 (70% Hydrazine/ 30% Water)					27.832	N_2H_4/H_2O	0.333	Mixed 70/30%
Hydrogen Cloride	808.79	55,746.0	1,646.2	80	36.461	HCl	2963.9	Pressurized Gas Only
Hydrogen Fluoride	18.70	1,288.94	38.06	80	20.006	HF	37.6	
Hydrogen Sulfide	326.6	22,509.0	664.7	80	34·080	H_2S	1118.6	
MAF 1, 3, & 4	(Z= 0.4, 0.2, and 0.6 for MAF 1, 3, and 4 respectively)							
Methylene Chloride	8.99	619.6	18.3	81	84.933	CH_2Cl_2	76.7	
Monomethylhydrazine (MMH)	1.0	68.9	2.04	80	46.072	CH_3NHNH_2	4.6	
Nitrogen Dioxide	15.70	1,082.35	31.96	80	46.006	NO_2	100.0	
Nitrogen Tetroxide	14.6	1,006.3	29.72	70	92.011	N_2O_4	135.0	
Oxygen Difuloride	4306.0	296,795.0	8,764.4	80	53.996	OF_2	23,369.2	Pressurized Gas Only
Perchloryl Fluoride	176.1	12,137.7	358.4	77	102.450	ClO_3F	1813.3	
Pentaborane	4.0	275.7	8.14	77	63.127	B_5H_9	25.4	
Sulfur Dioxide	55.03	3,793.6	112.03	80	64.063	SO_2	354.4	
Trichloroethylene	1.16	80.0	2.36	69.8	131.389	$CHClCCl_2$	15.3	
Trichlorotrifluoroethane	6.50	448.0	13.2	77	187.377	CCl_2FCClF_2	122.4	
Unsymmetrical Dimethylhydrazine(UDMH)	3.1	213.7	6.3	80	60.099	$(CH_3)_2N_2H_2$	18.7	
Nitrogen Trifluoride					71.002	NF_3		

Appendix D

TOXIC CORRIDOR LENGTH AS A FUNCTION OF TEMPERATURE DIFFERENCE ERRORS

Toxic corridor length calculations are quite sensitive to temperature difference (delta-T) values that are used. The sensitivity is greatest when the atmosphere is unstable, i.e., delta-T <0. The sensitivity decreases as delta-T increases. If the procedures for estimating delta-T are properly followed, any error should normally not be more than 1°F. If an error results when delta-T is estimated through use of Table B-1 in Appendix B, the error will most likely be in a positive sense, e.g., a "true" delta-T of 0°F might be estimated as +1°F. For this reason, toxic corridor lengths will usually be on the conservative or safe side, i.e., the corridor lengths will be longer than necessary rather than shorter.

A positive 1°F error when the "true" delta-T is -3°F (i.e., delta-T estimated as -2°F) will result in a 40 percent overestimation of the corridor length. An error in the opposite sense, i.e., delta-T estimated as -4°F, will cause the same corridor length to be underestimated by 32 percent.

When the "true" delta-T is positive, corridor length errors are smaller for similar errors in estimating delta-T. Suppose the "true" delta-T is 6°F and the estimate is 5°F. The toxic corridor will be underestimated by 15 percent. Conversely, a 7°F estimate of delta-T would result in a corridor length that is too large by 17 percent.

Figure D-1 graphically displays the resulting toxic corridor error percentages as a function of "true" delta-T and the error (E) that might occur in estimates. The error (E) ranges from -3°F to +3°F. An examination of the potential errors in toxic corridor lengths that might result from errors in estimating delta-T clearly signals the importance of using the best estimates of delta-T. Note that positive errors in delta-T may result in excessive evacuations of populated areas while negative delta-T errors could result in insufficient evacuations and a possibility of casualties in some nonevacuated areas.

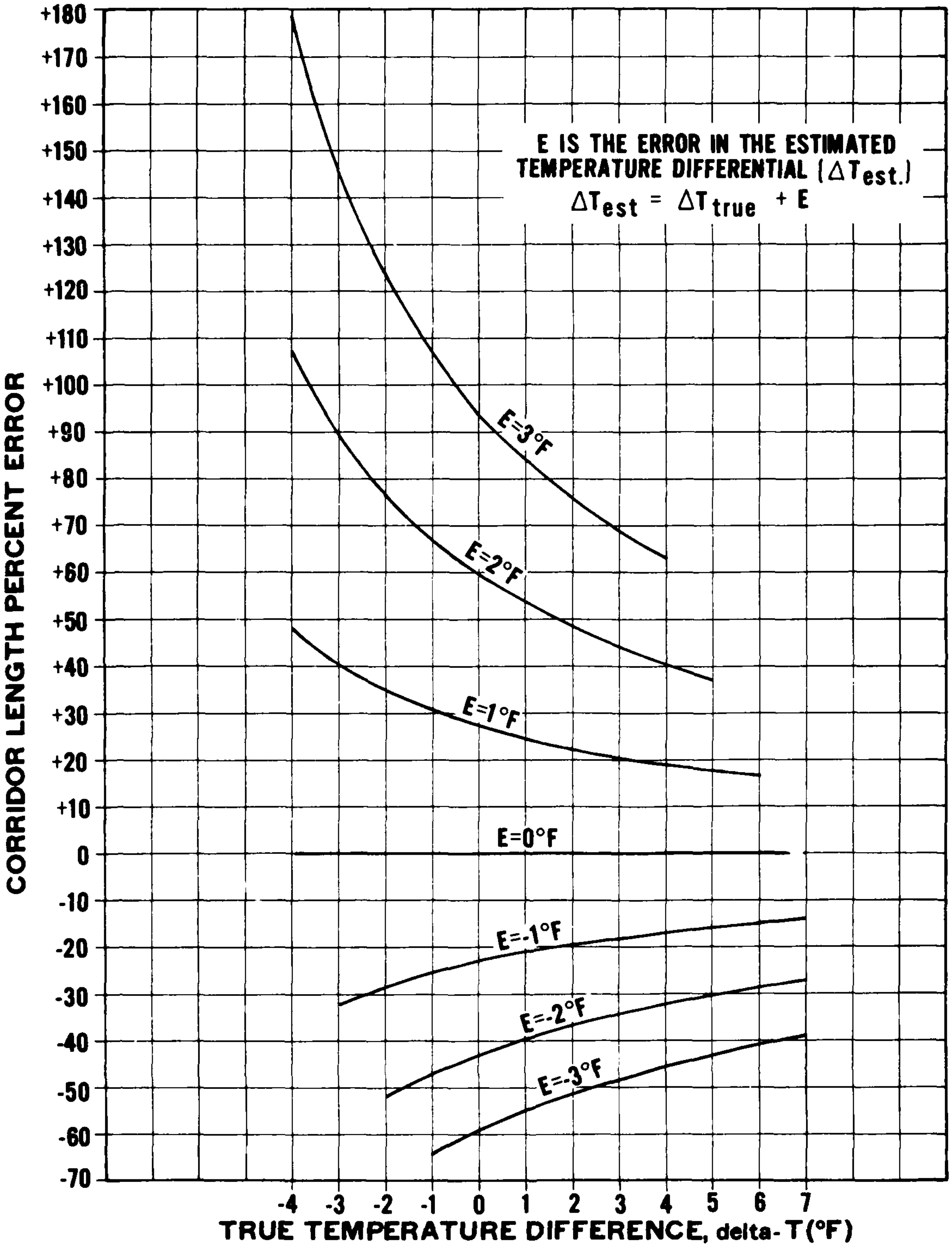


Figure D-1. Toxic Corridor Length Errors, Expressed in Percent, as a Function of Temperature Difference Errors.

Appendix E

EXAMPLE TOXIC CORRIDOR PROBLEMS

1. Situation: Spill of Anhydrous Ammonia

Spill Area: Unknown

Time of Day: Sunset

Sky: Clear

Ambient Air Temp: 30°C

Wind Speed/Direction: 6 kt/235 degrees; from Figure B-2(c)

Wind Variability (R): 65 degrees; from Figure B-2(c)

Delta-T: 0°F; from Table B-1

GMW: 17.03; from Table 33

Exposure Limit: 75 PPM; SPEL from Table 33

Source Strength: 1000 lb/min; estimated by DRF

TOXIC CORRIDOR LENGTH (FT) AND WIDTH (DEGREES)

	Method 1	Method 2	Method 3	Method 4
Length	9108	9143 (Table) 9360 (Figure)	9500	9108
Width (1.5R)	98°	98°	98°	98°

For Method 2: CF = 0.78 (Table 33 or Figure 3)

DF = 11,722 (Table 34)

DF = 12,000 (Figure 4)

$X = CF \cdot DF$

2. Situation: Spill of Aluminum Fluoride (AlF_3)

Spill Area: Unknown

Time of Day: Midnight

Sky: Clear (no snow on ground)

Ambient Air Temp: 20°C

Wind Speed/Direction: 6 kt/235 degrees; from Figure B-2(c)

Wind Variability (R): 65 degrees; from Figure B-2(c)

Delta-T: 5°F; from Table B-1

GMW: 83.98; from BEE

Exposure Limit: 10 mg/m³* 30-min Emergency Exposure Limit (No SPEL exists); from BEE

Source Strength: 100 lb/min; from DRF

* 10 mg/m³ converts to 2.9 PPM by volume. See "Exposure Limit" in Glossary for conversion procedures.

TOXIC CORRIDOR LENGTH (FT) AND WIDTH (DEGREES)

	Method 1	Method 2	Method 3	Method 4
Length	No Table	18,264 (Table) 18,300 (Figure)	18,000 (Figure 6)	18,246
Width (1.5R)	98°	98°	98°	98°

For Method 2: CF = 1.83 (Figure 3)

CF = 1.82 (Equation)

DF = 10,035 (Table 34)

DF = 10,000 (Figure 4)

$X = CF \cdot DF$

3. Situation: Spill of Hydrazine

Spill Area: 4000 feet^2

Time of Day: Sunrise

Sky: Clear

Ambient Air Temp: 24°C

Wind Speed/Direction: 11 kt/335 degrees

Wind Variability (R): 120 degrees; from Figure B-2(d)

Delta-T: 0°F

GMW: 32.045

Exposure Limit: 20 PPM; SPEL from Table 33

Source Strength: 14 lb/min; from Appendix C

TOXIC CORRIDOR LENGTH (FT) AND WIDTH (DEGREES)

	Method 1	Method 2	Method 3	Method 4
Length	1504	1510 (Table) 1430 (Figure)	1400	1452
Width (1.5R)	180°	180°	180°	180°

For Method 2: CF = 1 Figure 3

CF = 1.11; Table 33

DF = 1360; Table 34

DF = 1300; Figure 4

$X = CF \cdot DF$

Appendix F

SPECIAL TOXIC CORRIDOR TABLES FOR TITAN II SITES

This appendix contains additional Toxic Corridor Tables for use with Method 1. They have been included because of special requirements for multi types of hazard corridors at TITAN II missile sites. Note that tables based upon 10-, 30-, and 60-minute Short-Term Public Emergency Limit (SPEL) have been provided for Nitrogen Tetroxide, Hydrazine, and UDMH. Also the 10-minute Short-Term Public Limit (STPL) was used to produce tables for Nitrogen Tetroxide and UDMH. These tables are contained in SACR 355-5.

Table F-1. Hydrazine TCL Table (TITAN - Emergencies).

HAZARD CORRIDOR LENGTHS IN FEET FOR THE
10-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 30PPM (1ST NUMBER)
30-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 20PPM (2ND NUMBER)
60-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 10PPM (3RD NUMBER)

SOURCE STRENGTH LB/MIN	DELTA T (DEG F) -4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
1	100	200	200	300	400	400	500	600	800	900	1100	1200	1400	1600	1800
	200	200	300	300	400	500	600	800	900	1100	1300	1500	1700	2000	2200
	200	300	400	500	600	700	900	1100	1300	1500	1800	2100	2400	2800	3100
3	200	300	400	500	600	700	900	1100	1300	1500	1800	2100	2400	2800	3100
	200	300	400	600	700	900	1100	1300	1600	1900	2200	2600	3000	3400	3900
	300	400	600	800	1000	1200	1500	1900	2300	2700	3100	3600	4200	4800	5500
5	200	300	400	600	700	900	1200	1400	1700	2000	2300	2700	3100	3600	4100
	300	400	500	700	900	1100	1400	1700	2100	2400	2900	3300	3800	4400	5000
	400	500	700	[illegible]	1300	1600	2000	2400	2900	3500	4100	4700	5500	6200	7100
10	300	[illegible]	[illegible]	800	1000	1300	1600	2000	2400	2800	3300	3800	4400	5100	5800
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1600	2000	2400	2900	3500	4100	4700	5500	6200	7100
	[illegible]	[illegible]	[illegible]	1400	[illegible]	2300	2800	3400	4100	4900	5800	6700	7800	8900	10100
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1600	[illegible]	[illegible]	2900	3500	4100	[illegible]	5500	6200	7100
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2400	[illegible]	[illegible]	4200	[illegible]	[illegible]	6700	7700	8700
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9500	10900	12400
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6300	7200	8200
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7800	8900	10100
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11100	12700	14400
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7800	8900	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9500	10900	12400
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13600	15600	17700
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9000	10300	11700
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11100	12700	14400
	1000	[illegible]	[illegible]	[illegible]	[illegible]	4600	5700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15800	18100	20600
50	700	[illegible]	[illegible]	1800	[illegible]	2900	3600	4500	5400	6400	7500	8700	10100	11500	13100
	800	1200	[illegible]	[illegible]	[illegible]	3600	4500	5500	6600	7800	9200	10700	12400	14200	16200
	1100	1700	2300	[illegible]	[illegible]	5100	6400	7800	9400	11200	13100	15300	17700	20200	23000
75	800	1200	1600	2200	2800	3600	4500	5500	6600	7800	9200	10700	12400	14200	16200
	1000	1400	2000	2700	3500	4400	5500	6700	8100	9600	11300	13200	15200	17500	19900
	1400	2000	2800	3800	5000	6300	7800	9600	11500	13700	16100	18800	21700	24900	28400
100	900	1400	1900	2500	3300	4200	5200	6300	7600	9100	10700	12400	14400	16500	18700
	1100	1700	2300	3100	4000	5100	6400	7800	9400	11200	13100	15300	17700	20200	23000
	1600	2400	3300	4400	5700	7300	9100	11100	13400	15900	18700	21800	25200	28900	32900

Table F-1 (cont'd). Hydrazine TCL Table (TITAN - Emergencies).

HAZARD CORRIDOR LENGTHS IN FEET FOR THE
10-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 30PPM (1ST NUMBER)
30-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 20PPM (2ND NUMBER)
60-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 10PPM (3RD NUMBER)

SOURCE STRENGTH	DELTA T (DEG F)														
LB/MIN	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
120	1000	1500	2100	2800	3600	4600	5700	6900	8400	10000	11700	13600	15800	18100	20600
	1300	1800	2500	3400	4400	5600	7000	8500	10300	12200	14400	16800	19400	22200	25300
	1800	2600	3600	4800	6300	8000	9900	12200	14700	17400	20500	23900	27600	31700	36100
200	1300	1900	2700	3600	4700	5900	7400	9000	10900	12900	15200	17700	20500	23500	26700
	1600	2400	3300	4400	5700	7300	9100	11100	13400	15900	18700	21800	25200	28900	32900
	2300	3300	4700	6300	8200	10400	12900	15800	19000	22700	26700	31100	35900	41200	46900
400	1900	2700	3800	5100	6600	8400	10500	12800	15500	18400	21700	25300	29200	33400	38100
	2300	3300	4700	6300	8200	10400	12900	15800	19000	22700	26700	31100	35900	41200	46900
	3200	4700	6600	8900	11600	14800	18400	22500	27100	32300	38000	44300	51200	58700	66900
600	2300	3300	4700	6300	8200	10400	12900	15800	19000	22700	26700	31100	35900	41200	46900
	2800	4100	5700	7700	10000	12800	15900	19400	23400	27900	32800	38300	44200	50700	57700
	4000	5800	8100	11000	14300	18200	22600	27700	33400	39800	46800	54600	63100	72300	82300
1000	2900	4300	6000	8100	10600	13500	16800	20500	24700	29400	34600	40400	46700	53500	60900
	3600	5300	7400	10000	13000	16600	20600	25200	30400	36200	42600	49700	57400	65800	75000
	5100	7600	10600	14200	18600	23600	29400	36000	43400	51700	60800	70900	81900	93900	107000
1500	3600	5300	7400	10000	13000	16600	20600	25200	30400	36200	42600	49700	57400	65800	75000
	4400	6500	9100	12300	16000	20400	25400	31100	37500	44600	52500	61200	70700	81100	92300
	6300	9300	13000	17500	22800	29100	36200	44300	53400	63600	74900	87300	100900	115700	131700
2000	4200	6100	8600	11600	15100	19200	23900	29200	35300	42000	49400	57600	66600	76300	86900
	5100	7600	10600	14200	18600	23600	29400	36000	43400	51700	60800	70900	81900	93900	107000
	7300	10800	15100	20300	26500	33700	41900	51300	61900	73700	86800	101200	116900	134000	152600
3000	5100	7600	10600	14200	18600	23600	29400	36000	43400	51700	60800	70900	81900	93900	107000
	6300	9300	13000	17500	22800	29100	36200	44300	53400	63600	74900	87300	100900	115700	131700
	9000	13200	18500	25000	32600	41400	51600	63200	76200	90800	106900	124600	143900	165000	187900
4000	5900	8800	12200	16500	21500	27400	34100	41700	50300	59900	70500	82200	95000	108900	124000
	7300	10800	15100	20300	26500	33700	41900	51300	61900	73700	86800	101200	116900	134000	152600
	10400	15300	21500	28900	37700	48000	59800	73300	88400	105200	123800	144400	166800	191300	217800
5000	6700	9800	13700	18500	24100	30700	38200	46800	56400	67100	79100	92100	106500	122100	139000
	8200	12100	16900	22700	29700	37700	47000	57600	69400	82700	97300	113400	131100	150300	171100
	11700	17200	24100	32400	42300	53800	67100	82100	99100	117900	138900	161900	187000	214400	244200

Table F-2. Nitrogen Tetroxide TCL Table (TITAN - Operational).

HAZARD CORRIDOR LENGTHS IN FEET FOR THE
10-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 1PPM

SOURCE STRENGTH LB/MIN	DELTA T (DEG F) -4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
1	400	600	900	1200	1500	1900	2300	2900	3400	4100	4800	5600	6500	7400	8400
3	700	1100	1500	2000	2600	3300	4100	5000	6000	7100	8400	9800	11300	13000	14700
5	1000	1400	1900	2600	3400	4300	5300	6500	7800	9300	10900	12700	14700	16800	19200
10	1300	2000	2700	3700	4800	6100	7500	9200	11100	13200	15600	18100	20900	24000	27300
15	1600	2400	3400	4500	5900	7400	9300	11300	13700	16300	19100	22300	25800	29500	33600
20	1900	2800	3900	5200	6800	8600	10700	13100	15800	18800	22200	25800	29800	34200	39000
30	2300	3400	4800	6400	8300	10600	13200	16200	19500	23200	27300	31800	36700	42100	47900
40	2700	3900	5500	7400	9700	12300	15300	18700	22600	26900	31600	36800	42600	48800	55600
50	3000	4400	6200	8300	10800	13800	17100	21000	25300	30100	35400	41300	47700	54700	62300
75	3700	5400	7600	10200	13300	16900	21100	25800	31100	37100	43600	50800	58800	67400	76700
100	4300	6300	8800	11800	15400	19600	24400	29900	36100	42900	50600	58900	68100	78100	88900
200	6100	9000	12500	16900	22000	28000	34900	42700	51500	61300	72100	84100	97100	111400	126800
300	7500	11000	15400	20700	27100	34400	42900	52500	63300	75400	88800	103500	119600	137100	156100
400	8600	12800	17900	24000	31400	39900	49700	60900	73400	87400	102900	119900	138600	158900	180900
500	9700	14300	20000	26900	35200	44700	55700	68200	82300	98000	115400	134500	155400	178200	202900
1000	13800	20400	28500	38400	50200	63800	79500	97400	117400	139800	164600	191900	221700	254200	289500
2000	19700	29100	40700	54800	71600	91100	113500	138900	167600	199500	234900	273800	316400	362800	413100
3000	24200	35800	50100	67500	88100	112100	139700	171000	206300	245600	289200	337100	389600	446700	508500
4000	28100	41400	58100	78200	102100	129900	161900	198200	239100	284700	335200	390700	451500	517700	589400
5000	31500	46500	65100	87700	114500	145700	181500	222300	268100	319200	375800	438100	506300	580500	660900

Table F-3. Nitrogen Tetroxide TCL Table (TITAN - Emergencies).

HAZARD CORRIDOR LENGTHS IN FEET FOR THE
10-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 5PPM (1ST NUMBER)
30-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 3PPM (2ND NUMBER)
60-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 2PPM (3RD NUMBER)

SOURCE STRENGTH LB/MIN	DELTA T (DEG F) -4	-3	-2	-1	0	1	2	3	4	5	6	7	8	.9	10
1	200	300	400	500	700	900	1100	1300	1500	1800	2100	2500	2900	3300	3700
	300	400	500	700	900	1100	1400	1700	2000	2300	2800	3200	3700	4200	4800
	300	500	600	800	1100	1300	1700	2000	2400	2900	3400	3900	4500	5200	5900
3	400	500	700	900	1200	1500	1800	2200	2700	3200	3700	4300	5000	5700	6500
	400	600	900	1200	1500	1900	2300	2900	3400	4100	4800	5600	6500	7400	8400
	500	800	1100	1400	1800	2300	2900	3500	4200	5000	5900	6900	7900	9100	10400
5	400	600	900	1200	1500	1900	2300	2900	3400	4100	4800	5600	6500	7400	8400
	600	800	1100	1500	1900	2400	3000	3700	4500	5300	6200	7300	8400	9600	10900
	700	1000	1400	1800	2400	3000	3700	4600	5500	6500	7700	8900	10300	11800	13400
10	600	900	1200	1600	2100	2700	3300	4100	4900	5800	6800	8000	9200	10500	12000
	800	1100	1600	2100	2700	3500	4300	5300	6300	7500	8900	10300	11900	13700	15600
	1000	1400	1900	2600	3400	4300	5300	6500	7800	9300	10900	12700	14700	16800	19200
15	700	1100	1500	2000	2600	3300	4100	5000	6000	7100	8400	9800	11300	13000	14700
	1000	1400	1900	2600	3400	4300	5300	6500	7800	9300	10900	12700	14700	16800	19200
	1200	1700	2400	3200	4100	5200	6500	8000	9600	11400	13400	15600	18100	20700	23600
20	900	1200	1700	2300	3000	3800	4700	5800	7000	8300	9700	11300	13100	15000	17100
	1100	1600	2200	3000	3900	4900	6100	7500	9000	10700	12600	14700	17000	19500	22200
	1300	2000	2700	3700	4800	6100	7500	9200	11100	13200	15600	18100	20900	24000	27300
30	1000	1500	2100	2800	3700	4700	5800	7100	8600	10200	12000	14000	16100	18500	21000
	1300	2000	2700	3700	4800	6100	7500	9200	11100	13200	15600	18100	20900	24000	27300
	1600	2400	3400	4500	5900	7400	9300	11300	13700	16300	19100	22300	25800	29500	33600
40	1200	1800	2400	3300	4300	5400	6700	8200	9900	11800	13900	16200	18700	21400	24400
	1600	2300	3200	4200	5500	7000	8700	10700	12900	15300	18000	21000	24300	27800	31600
	1900	2800	3900	5200	6800	8600	10700	13100	15800	18800	22200	25800	29800	34200	39000
50	1300	2000	2700	3700	4800	6100	7500	9200	11100	13200	15600	18100	20900	24000	27300
	1700	2500	3500	4700	6200	7900	9800	12000	14400	17200	20200	23500	27200	31200	35500
	2100	3100	4300	5800	7600	9700	12000	14700	17700	21100	24900	29000	33500	38400	43700
75	1600	2400	3400	4500	5900	7400	9300	11300	13700	16300	19100	23300	25800	29500	33600
	2100	3100	4300	5800	7600	9700	12000	14700	17700	21100	24900	29000	33500	38400	43700
	2600	3800	5300	7200	9300	11900	14800	18100	21800	26000	30600	35600	41200	47200	53800
100	1900	2800	3900	5200	6800	8600	10700	13100	15800	18800	22200	25800	29800	34200	39000
	2500	3600	5000	6800	8800	11200	13900	17000	20600	24500	28800	33600	38800	44500	50600
	3000	4400	6200	8300	10800	13800	17100	21000	25300	30100	35400	41300	47700	54700	62300

Table F-3 (cont'd). Nitrogen Tetroxide TCL Table (TITAN - Emergencies).

HAZARD CORRIDOR LENGTHS IN FEET FOR THE
10-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 5PPM (1ST NUMBER)
30-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 3PPM (2ND NUMBER)
60-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 2PPM (3RD NUMBER)

SOURCE STRENGTH LB/MIN	DELTA T (DEG F) -4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
120	2100	3000	4300	5700	7400	9500	11800	14400	17400	20700	24300	28400	32800	37600	42800
	2700	3900	5500	7400	9700	12300	15300	18700	22600	26900	31600	36800	42600	48800	55600
	3300	4800	6800	9100	11900	15100	18800	23000	27800	33100	38900	45400	52400	60100	68400
200	2700	3900	5500	7400	9700	12300	15300	18700	22600	26900	31600	36800	42600	48800	55600
	3500	5100	7200	9600	12500	15900	19900	24300	29300	34900	41100	47900	55300	63400	72200
	4300	6300	8800	11800	15400	19600	24400	29900	36100	42900	50600	58900	68100	78100	88900
400	3800	5600	7800	10600	13800	17500	21800	26700	32200	38300	45100	52600	60700	69600	79300
	4900	7300	10200	13700	17900	22700	28300	34700	41800	49800	58600	68300	78900	90500	103000
	6100	9000	12500	16900	22000	28000	34900	42700	51500	61300	72100	84100	97100	111400	126800
600	4700	6900	9700	13000	16900	21500	26800	32800	39600	47200	55500	64700	74800	85700	97600
	6100	9000	12500	16900	22000	28000	34900	42700	51500	61300	72100	84100	97100	111400	126800
	7500	11000	15400	20700	27100	34400	42900	52500	63300	75400	88800	103500	119600	137100	156100
1000	6100	9000	12500	16900	22000	28000	34900	42700	51500	61300	72100	84100	97100	111400	126800
	7900	11600	16300	21900	28600	36300	45300	55400	66900	79600	93700	109200	126200	144700	164800
	9700	14300	20000	26900	35200	44700	55700	68200	82300	98000	115400	134500	155400	178200	202900
1500	7500	11000	15400	20700	27100	34400	42900	52500	63300	75400	88800	103500	119600	137100	156100
	9700	14300	20000	26900	35200	44700	55700	68200	82300	98000	115400	134500	155400	178200	202900
	11900	17600	24600	33200	43300	55100	68600	84000	101300	120600	142000	165600	191300	219400	249800
2000	8600	12800	17900	24000	31400	39900	49700	60900	73400	87400	102900	119900	138600	158900	180900
	11200	16600	23200	31200	40700	51800	64600	79100	95400	113600	133700	155900	180100	206500	235100
	13800	20400	28500	38400	50200	63800	79500	97400	117400	139800	164600	191900	221700	254200	289500
3000	10600	15700	22000	29600	38600	49100	61200	74900	90400	107600	126700	147700	170600	195600	222700
	13800	20400	28500	38400	50200	63800	79500	97400	117400	139800	164600	191900	221700	254200	289500
	17000	25100	35100	47300	61700	78600	97900	119900	144600	172100	202700	236300	273000	313000	356400
4000	12300	18200	25500	34300	44700	56900	70900	86800	104700	124700	146800	171100	197800	226700	258200
	16000	23600	33100	44500	58100	74000	92200	112800	136100	162100	190800	222400	257000	294700	335500
	19700	29100	40700	54800	71600	91100	113500	138900	167600	199500	234900	273800	316400	362800	413100
5000	13800	20400	28500	38400	50200	63800	79500	97400	117400	139800	164600	191900	221700	254200	289500
	17900	26500	37100	49900	65200	82900	103300	126500	152600	181700	213900	249400	288200	330400	376200
	22100	32600	45600	61500	80200	102100	127200	155800	187900	223700	263400	307000	354800	406800	463100

Table F-4. Unsymmetrical Dimethylhydrazine (UDMH) TCL Table (TITAN - Operational).

HAZARD CORRIDOR LENGTHS IN FEET FOR THE
10-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 50PPM

SOURCE STRENGTH LB/MIN	DELTA T (DEG F) -4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
1	100	100	100	200	200	300	300	400	400	500	600	700	800	900	1000
3	100	200	200	300	300	400	500	600	700	900	1000	1200	1400	1600	1800
5	200	200	300	300	400	500	700	800	1000	1100	1300	1500	1800	2000	2300
10	200	300	400	500	600	800	900	1100	1300	1600	1900	2200	2500	2900	3200
15	200	300	400	600	700	[illegible]	1100	1400	1600	1900	2300	2700	3100	3500	4000
20	[illegible]	[illegible]	500	700	800	1100	1300	1600	1900	2300	2600	3100	3500	4100	4600
30	[illegible]	[illegible]	600	800	1000	1300	1600	1900	2300	2800	3200	3800	4300	5000	5700
40	[illegible]	[illegible]	700	900	1200	1500	1800	2200	2700	3200	3700	4400	5000	5800	6600
50	[illegible]	[illegible]	800	1000	1300	1700	2100	2500	3000	3600	4200	4900	5600	6500	7300
75	500	700	900	1200	1600	2000	2500	3100	3700	4400	5200	6000	6900	7900	9000
100	[illegible]	800	1100	1400	1900	2300	2900	3600	4300	5100	6000	7000	8000	9200	10500
200	800	1100	1500	2000	2600	3300	4100	5000	6100	7200	8500	9900	11400	13100	14900
300	900	1300	1900	2500	[illegible]	4100	5100	6200	7500	8900	10400	12200	14100	16100	18300
400	1100	1500	2100	2900	3700	4700	5900	7200	8600	10300	12100	14100	16300	18700	21200
500	1200	1700	2400	3200	4200	5300	6600	8000	9700	11500	13600	15800	18300	20900	23800
1000	1700	2400	3400	4500	5900	7500	9400	11500	13800	16400	19300	22500	26000	29800	34000
2000	2400	3400	4800	6500	8400	10700	13300	16300	19700	23400	27600	32100	37100	42600	48500
3000	2900	4200	5900	8000	10400	13200	16400	20100	24200	28800	33900	39600	45700	52400	59600
4000	3300	4900	6800	9200	12000	15300	19000	23300	28100	33400	39300	45800	53000	60700	69100
5000	3700	5500	7700	10300	13500	17100	21300	26100	31500	37500	44100	51400	59400	68100	77500

Table F-5. Unsymmetrical Dimethylhydrazine (UDMH) TCL Table (TITAN - Emergencies).

HAZARD CORRIDOR LENGTHS IN FEET FOR THE
10-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 100PPM (1ST NUMBER)
30-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 50PPM (2ND NUMBER)
60-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 30PPM (3RD NUMBER)

SOURCE STRENGTH LB/MIN	DELTA T (DEG F) -4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
1	100	100	100	100	200	200	200	300	300	400	400	500	600	700	700
	100	100	100	200	200	300	300	400	400	500	600	700	800	900	1000
	100	100	200	200	300	300	400	500	600	700	800	900	1000	1200	1300
3	100	100	200	200	300	300	400	500	500	600	700	900	1000	1100	1300
	100	200	200	300	300	400	500	600	700	900	1000	1200	1400	1600	1800
	200	200	300	300	400	500	700	800	1000	1100	1300	1500	1800	2000	2300
5	100	200	200	300	300	400	500	600	700	800	900	1100	1300	1400	1600
	200	200	300	300	400	500	700	800	1000	1100	1300	1500	1800	2000	2300
	200	300	300	400	600	700	800	1000	1200	1500	1700	2000	2300	2600	3000
10	200	200	300	300	400	500	700	800	1000	1100	1300	1500	1800	2000	2300
	200	300	400	500	600	800	900	1100	1300	1600	1900	2200	2500	2900	3200
	200	300	500	600	800	1000	1200	1400	1700	2100	2400	2800	3200	3700	4200
15	200	200	300	400	500	700	800	1000	1200	1400	1600	1900	2200	2500	2800
	200	300	400	600	700	900	1100	1400	1600	1900	2300	2700	3100	3500	4000
	300	400	600	700	900	1200	1500	1800	2100	2500	3000	3400	4000	4500	5200
20	200	300	400	500	600	800	900	1100	1300	1600	1900	2200	2500	2900	3200
	300	400	500	700	800	1100	1300	1600	1900	2300	2600	3100	3500	4100	4600
	300	500	600	800	1100	1400	1700	2000	2500	2900	3400	4000	4600	5300	6000
30	200	300	400	600	700	900	1100	1400	1600	1900	2300	2700	3100	3500	4000
	300	400	600	800	1000	1300	1600	1900	2300	2800	3200	3800	4300	5000	5700
	400	600	800	1000	1300	1700	2100	2500	3000	3600	4200	4900	5600	6500	7300
40	300	400	500	700	800	1100	1300	1600	1900	2300	2600	3100	3500	4100	4600
	400	500	700	900	1200	1500	1800	2200	2700	3200	3700	4400	5000	5800	6600
	500	600	900	1200	1500	1900	2400	2900	3500	4100	4900	5700	6500	7500	8500
50	300	400	600	700	900	1200	1500	1800	2100	2500	3000	3400	4000	4500	5200
	400	600	800	1000	1300	1700	2100	2500	3000	3600	4200	4900	5600	6500	7300
	500	700	1000	1300	1700	2100	2700	3200	3900	4600	5400	6300	7300	8400	9500
75	300	500	700	900	1100	1400	1800	2200	2600	3100	3600	4200	4900	5600	6300
	500	700	900	1200	1600	2000	2500	3100	3700	4400	5200	6000	6900	7900	9000
	600	900	1200	1600	2100	2600	3300	4000	4800	5700	6700	7800	9000	10300	11700
100	400	600	800	1000	1300	1700	2100	2500	3000	3600	4200	4900	5600	6500	7300
	500	800	1100	1400	1900	2300	2900	3600	4300	5100	6000	7000	8000	9200	10500
	700	1000	1400	1800	2400	3000	3800	4600	5500	6600	7700	9000	10400	11900	13600

Table F-5 (cont'd). Unsymmetrical Dimethylhydrazine (UDMH) TCL Table (TITAN - Emergencies).

HAZARD CORRIDOR LENGTHS IN FEET FOR THE
10-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 100PPM (1ST NUMBER)
30-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 50PPM (2ND NUMBER)
60-MINUTE SHORT-TERM PUBLIC EMERGENCY LIMIT, 30PPM (3RD NUMBER)

SOURCE STRENGTH LB/MIN	DELTA T (DEG F) -4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
120	400	600	800	1100	1400	1800	2200	2700	3300	3900	4600	5400	6200	7100	8100
	600	900	1200	1600	2000	2600	3200	3900	4700	5600	6500	7600	8800	10100	11500
	800	1100	1500	2000	2600	3300	4100	5000	6100	7200	8500	9900	11400	13100	14900
200	500	800	1100	1400	1900	2300	2900	3600	4300	5100	6000	7000	8000	9200	10500
	800	1100	1500	2000	2600	3300	4100	5000	6100	7200	8500	9900	11400	13100	14900
	1000	1400	2000	2600	3400	4300	5400	6500	7900	9400	11000	12800	14800	17000	19400
400	800	1100	1500	2000	2600	3300	4100	5000	6100	7200	8500	9900	11400	13100	14900
	1100	1500	2100	2900	3700	4700	5900	7200	8600	10300	12100	14100	16300	18700	21200
	1400	2000	2800	3700	4800	6100	7600	9300	11200	13400	15700	18300	21200	24200	27600
600	900	1300	1900	2500	3200	4100	5100	6200	7500	8900	10400	12200	14100	16100	18300
	1300	1900	2600	3500	4600	5800	7200	8800	10600	12700	14900	17400	20000	23000	26100
	1700	2400	3400	4500	5900	7500	9400	11500	13800	16400	19300	22500	26000	29800	34000
1000	1200	1700	2400	3200	4200	5300	6600	8000	9700	11500	13600	15800	18300	20900	23800
	1700	2400	3400	4500	5900	7500	9400	11500	13800	16400	19300	22500	26000	29800	34000
	2100	3100	4400	5900	7700	9800	12200	14900	17900	21300	25100	29300	33800	38800	44100
1500	1400	2100	2900	3900	5100	6500	8100	9900	11900	14200	16700	19400	22500	25800	29300
	2000	3000	4200	5600	7300	9300	11500	14100	17000	20200	23800	27700	32000	36700	41800
	2600	3900	5400	7200	9400	12000	15000	18300	22100	26300	30900	36000	41600	47700	54300
2000	1700	2400	3400	4500	5900	7500	9400	11500	13800	16400	19300	22500	26000	29800	34000
	2400	3400	4800	6500	8400	10700	13300	16300	19700	23400	27600	32100	37100	42600	48500
	3000	4500	6200	8400	10900	13900	17300	21200	25600	30400	35800	41700	48200	55300	63000
3000	2000	3000	4200	5600	7300	9300	11500	14100	17000	20200	23800	27700	32000	36700	41800
	2900	4200	5900	8000	10400	13200	16400	20100	24200	28800	33900	39600	45700	52400	59600
	3700	5500	7700	10300	13500	17100	21300	26100	31500	37500	44100	51400	59400	68100	77500
4000	2400	3400	4800	6500	8400	10700	13300	16300	19700	23400	27600	32100	37100	42600	48500
	3300	4900	6800	9200	12000	15300	19000	23300	28100	33400	39300	45800	53000	60700	69100
	4300	6400	8900	12000	15600	19800	24700	30200	36500	43400	51100	59600	68800	78900	89800
5000	2600	3900	5400	7200	9400	12000	15000	18300	22100	26300	30900	36000	41600	47700	54300
	3700	5500	7700	10300	13500	17100	21300	26100	31500	37500	44100	51400	59400	68100	77500
	4800	7100	10000	13400	17500	22200	27700	33900	40900	48700	57300	66800	77100	88500	100700

Appendix G

TABLE OF THE ELEMENTS

ELEMENT	SYMBOL	ATOMIC NUMBER	ATOMIC WEIGHT (C = 12)
actinium	Ac	89	--
aluminum	Al	13	26.9815
americium	Am	95	--
antimony	Sb	51	121.75
argon	Ar	18	39.948
arsenic	As	33	74.9216
astatine	At	85	--
barium	Ba	56	137.34
berkelium	Bk	97	--
beryllium	Be	4	9.01218
bismuth	Bi	83	208.9806
boron	B	5	10.81
bromine	Br	35	79.904
cadmium	Cd	48	112.40
calcium	Ca	20	40.08
californium	Cf	98	--
carbon	C	6	12.011
cerium	Ce	58	140.12
cesium	Cs	55	135.9055
chlorine	Cl	17	35.453
chromium	Cr	24	51.996
cobalt	Co	27	58.9332
columbium	Cb	(see niobium)	--
copper	Cu	29	63.546
curium	Cm	96	--
dysprosium	Dy	66	162.50
einsteinium	Es	99	--
erbium	Er	68	167.26
europium	Eu	63	151.96
fermium	Fm	100	--
fluorine	F	9	18.9984
francium	Fr	87	--
gadolinium	Gd	64	157.25
gallium	Ga	31	69.72
germanium	Ge	32	72.59
gold	Au	79	196.9665
hafnium	Hf	72	178.49
helium	He	2	4.00260
holmium	Ho	67	164.9303
hydrogen	H	1	1.0080

ELEMENT	SYMBOL	ATOMIC NUMBER	ATOMIC WEIGHT (C = 12)
indium	In	49	114.82
iodine	I	53	126.9045
iridium	Ir	77	192.22
iron	Fe	26	55.847
krypton	Kr	36	83.80
lanthanum	La	57	138.9055
lawrencium	Lr	103	--
lead	Pb	82	207.2
lithium	Li	3	6.941
lutetium	Lu	71	174.97
magnesium	Mg	12	24.305
manganese	Mn	25	54.9380
mendelevium	Md	101	--
mercury	Hg	80	200.59
molybdenum	Mo	42	95.94
neodymium	Nd	60	144.24
neon	Ne	10	20.179
neptunium	Np	93	237.0482
nickel	Ni	28	58.71
niobium	Nb	41	92.9064
nitrogen	N	7	14.0067
nobelium	No	102	--
osmium	Os	76	190.2
oxygen	O	8	15.9994
palladium	Pd	46	106.4
phosphorus	P	15	30.9738
platinum	Pt	78	195.09
plutonium	Pu	94	--
polonium	Po	84	--
potassium	K	19	39.102
praseodymium	Pr	59	140.9077
promethium	Pm	61	--
protactinium	Pa	91	231.0359
radium	Ra	88	226.0254
radon	Rn	86	--
rhenium	Re	75	186.2
rhodium	Rh	45	102.9055
rubidium	Rb	37	85.4678
ruthenium	Ru	44	101.07
samarium	Sm	62	150.4
scandium	Sc	21	44.9559
selenium	Se	34	78.96
silicon	Si	14	28.086

ELEMENT	SYMBOL	ATOMIC NUMBER	ATOMIC WEIGHT (C = 12)
silver	Ag	47	107.868
sodium	Na	11	22.9898
strontium	Sr	38	87.62
sulfur	S	16	32.06
tantalum	Ta	73	180.9479
technetium	Tc	43	98.9062
tellurium	Te	52	127.60
terbium	Tb	65	158.9254
thallium	Tl	81	204.37
thorium	Th	90	232.0381
thulium	Tm	69	168.9342
tin	Sn	50	118.69
titanium	Ti	22	47.90
tungsten	W	74	183.85
uranium	U	92	238.029
vanadium	V	23	50.9414
wolfram	W	(see tungsten)	--
xenon	Xe	54	131.30
ytterbium	Yb	70	173.04
yttrium	Y	39	88.9059
zinc	Zn	30	65.37
zirconium	Zr	40	91.22

GLOSSARY OF TERMS, ABBREVIATIONS, AND SYMBOLS

TERMS

Delta-T. Temperature difference between heights of 54 and 6 feet.

Emergency Exposure Limit (EEL). A short-term exposure limit which is used in an accidental release of a toxic chemical. These releases should be rare. The workers are knowledgeable of possible exposure and are subjected to periodical medical examination. These limits were established by a panel of experts appointed by the National Academy of Sciences - National Research Council, Committee on Toxicology. Concentrations are such that reversible toxic effects and discomfort, short of actual incapacitation, may well occur.

Exposure Limit. An atmospheric concentration of a toxic chemical that must not be exceeded. Exposure limits are established for the industrial community and the general public. Some of these include the Short-Term Public Emergency Limit (SPEL). Emergency Exposure Limit (EEL), and Short-Term Public Limit (STPL). Exposure limits may be expressed in Parts Per Million (PPM) by volume or in mass per unit volume (e.g., milligrams per cubic meter). Since the techniques contained in this report call for exposure limits in PPM, the conversion factors listed below may be used to convert to PPM from mass per unit volume units:

To convert to PPM (Vol) from

mg/m^3, multiply by 24.3/GMW or from

$\mu g/m^3$, multiply by 2.43×10^{-2}/GMW

where GMW is the gram molecular weight of the toxic chemical for which the exposure limit applies.

Hazard Corridors. The term "hazard" is frequently used interchangeably with the term "toxic" when reference is made to a corridor to be evacuated as the result of a release into the atmosphere of a toxic and, occasionally, explosive chemical. A hazard corridor considers both toxic and explosive risks to the public and will be the larger corridor determined from the appropriate considerations. If the corridor determined from explosive considerations is contained within that determined from toxic considerations, the hazard corridor will be identical to the toxic corridor. Weather personnel will be involved only with calculating "toxic" corridors which may or may not be determined to be "hazard" corridors by appropriate disaster response personnel.

Ocean Breeze and Dry Gulch Equation. This is an equation developed at the Air Force Cambridge Research Laboratories (now the Air Force Geophysics Laboratory) to determine downwind peak concentration of airborne contaminants from a continuous point source. This empirically derived equation was developed from data collected during extensive diffusion experiments with tracer releases simulating ground-level continuous point sources. Using independent data, the normalized peak concentrations obtained from this equation have been found to be accurate within a factor of two, 65 percent of the time and within a factor of four, 94 percent of the time. The equation is

$$C_p/Q = 1.75 \times 10^{-4} X^{-1.95} (\Delta T + 10)^{4.92}$$

This report is concerned with downwind distance, X, at which a predetermined concentration, C_p, will occur for a known source strength, Q, and temperature difference, delta-T (ΔT). The equation above was inverted and solved for the downwind distance X. In the process, appropriate changes were made to the coefficient to convert from metric units to English units and a factor was added to convert Cp/Q from units of seconds per cubic meter to units of PPM per lb/min. The converted equation, which was used to generate the Toxic Corridor Length Tables in this report is

AD-A101 267 AIR WEATHER SERVICE SCOTT AFB IL F/G 13/2
CALCULATING TOXIC CORRIDORS.(U)
NOV 80 J P KAHLER, R G CURRY, R A KANDLER
UNCLASSIFIED AWS/TR-80/003 SBIE-AD-E850 059 NL

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$$X = P\left[3.28 \left(\frac{29.75}{GMW}\right)^{0.513} \left(\frac{C_p}{Q}\right)^{-0.513} (\Delta T + 10)\right]^{2.53}$$

where X = downwind distance in feet. As used here, this distance defines a toxic corridor length.

P = a probability factor used to determine the probability that a specified concentration is not exceeded outside the corridor. Calculations in this report assume a 90-percent probability; therefore, P is equal to 1.63. Probability factors corresponding to other probabilities can be found in Table 35.

GMW = gram molecular weight of the toxic chemical.

C_p = peak concentration in parts per million by volume (PPM) along a plume centerline and at a height of approximately 5 feet above the ground at a given downwind travel distance, X, in feet. Toxic corridor lengths are calculated by using a specified exposure limit for C_p in the above equation.

Q = source strength in lb/min.

ΔT = the temperature in ^{o}F at 54 feet minus the temperature at 6 feet (NOTE: A negative ΔT means a decrease of temperature with height and a positive ΔT means an increase with height.)

Operational Toxic Corridor. (This term was established by the Strategic Air Command in connection with TITAN missile operations.) If an actual propellant spill or mishap occurs, an operational toxic (or "hazard" as it's sometimes called) corridor will be required. The calculated corridor will be periodically updated as meteorological and/or source strength information becomes more clearly defined.

Propellant Emission Corridor. (This term was established by the Strategic Air Command in connection with TITAN missile operations.) This corridor, which was formerly termed the "Intentional Released Corridor," will be established when planned emissions of propellants are to occur (e.g., tank venting or purging operations). As this is a scheduled occurrence, a determination must be made as to whether the planned task can be performed without unacceptable exposure to the general public.

Potential Toxic Corridor. (This term was established by the Strategic Air Command in connection with TITAN missile operations.) This corridor, which is sometimes referred to as a "Potential Toxic Corridor," will be calculated when propellants are in a nonstatic mode where no release of propellant to the environment is planned. This corridor should be updated as meteorological and/or potential source strengths change during an operation.

Public Emergency Limit (PEL). See Short-Term Public Emergency Limit (SPEL). The Committee on Toxicology (1979) renamed PELs as SPELs to avoid possible confusion with the OSHA term "permissible exposure limit."

Short-Term Public Emergency Limit (SPEL). This exposure limit will normally be used in calculating Potential and Operational Toxic Corridors at TITAN missile sites. It is a short-term exposure limit which is used in an accidental release of a toxic chemical involving the general public. These releases are expected to be rare events. A SPEL assumes that some temporary discomfort may accrue to the public, but that any effect resulting from the exposure is reversible and without residual

damage. These limits were established by a panel of experts appointed by the National Academy of Sciences - National Research Council, Committee on Toxicology. Consultation with members of this panel led to the selection of the exposure limits used in this report. The Committee on Toxicology recently renamed the "PEL" to "SPEL" for "Short-Term Public Emergency Limit." This was done to prevent confusion with the OSHA "Permissible Exposure Limit" which has a different meaning and intended use.

Short-Term Public Limit (STPL). This is an exposure limit that will normally be used to compute Propellant Emission Corridors at TITAN missile sites. Several tables for 10-minute STPLs are published in Appendix F primarily for use by weather personnel supporting SAC TITAN missile sites.

Solar Elevation. The angle between the sun and the horizon.

Source Strength (SS or Q). The rate in mass per unit time, expressed in this report in pounds per minute, at which a toxic chemical is released into the atmosphere. The source strength of a liquid spill of toxic chemical is determined by its rate of evaporation.

Temperature Difference (delta-T). The temperature change in the vertical. Delta-T is used to estimate the stability of the lower atmosphere and, thus, the amount of vertical mixing. Table B-1 is based on delta-T values calculated by subtracting the temperature (^{o}F) at 6 feet above ground from the temperature at 54 feet above ground.

Toxic Chemical. The chemical which could constitute a health hazard, if it is released into the atmosphere.

Toxic Corridor. The area within which the forecast concentration of a toxic chemical equals or exceeds a specified exposure limit. Toxic corridors are expressed in terms of length (X) in feet and width (W) in degrees of azimuth.

Wetted Area. Surface area covered by a spilled liquid chemical.

Wind Variability (R). As used in this report, R is the difference in degrees between the third largest fluctuation on each side of the mean wind direction when a 10-minute wind direction trace is used. As an approximation to this when only a 2-minute observation of a wind direction indicator is available, R is the difference in degrees between the largest fluctuation on each side of the mean wind direction. R is an index of the lateral diffusion of a toxic chemical in the atmosphere.

ABBREVIATIONS AND SYMBOLS

A	Area
AFGL	Air Force Geophysics Laboratory
AWS	Air Weather Service
BEE	Bioenvironmental Engineer
C_P	Peak concentration of an airborne toxic chemical - See Ocean Breeze and Dry Gulch equation in the Glossary of Terms for more information on this term.
CF	Chemical Factor
D	Mean wind direction in degrees of azimuth
Delta T	Temperature differential between 54- and 6-foot heights
DF	Diffusion Factor
ΔT	Same as Delta-T
DRF	Disaster Response Force
E	Error (see Figure D-1)
EEL	Emergency Exposure Limit
GMW	Gram Molecular Weight
in Hg	Inches of Mercury
mg	Milligram (10^{-3} gram)
μg	Microgram (10^{-6} gram)
mb	Millibar
P	Probability factor (see Table 35)
PEL	Public Emergency Limit; replaced by SPEL
PPAR	Percent Parameter. This is the same as the probability factor (P). (See Table 35)
PPM	Parts per million by volume
psi	Pounds per square inch
P_v	Vapor Pressure
Q	Source strength in mass per unit time
R	Wind direction variability in degrees
SPEL	Short-Term Public Emergency Limit; replaced PEL
SS	Source strength in mass per unit time
STPL	Short-Term Public Limit
T_P	Toxic Chemical pool temperature in ^{o}C
TC	Toxic Corridor
TCL	Toxic Corridor Length
V	Wind Velocity
W	Toxic Corridor Width in degrees of azimuth
X	Downwind distance in feet
Z	Source strength correction factor for evaporative sources (See Appendix C)

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TOXIC CORRIDOR WORKSHEET

Name of Chemical ____________________

1. Source strength _________________lbs/min (from environmental health service, disaster response force, or estimated)

2. 54-6 foot delta-T __________ ^{o}F (from instrument or table)

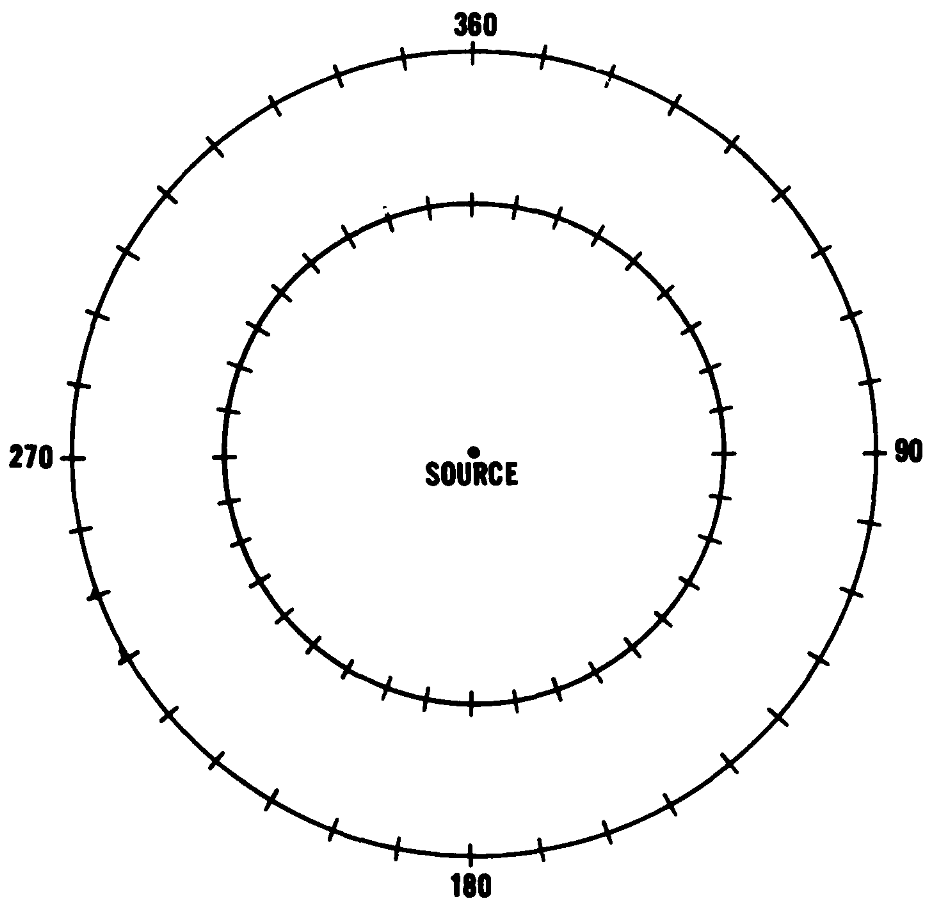
3. Toxic Corridor length ___________feet (from toxic corridor table)

4. Mean surface wind ____________________; wind variability (R) _____________ degrees (from wind trace, instrument dial, or estimated)

5. Corridor width (W) _________ degrees (W = 1.5R)

6. Toxic corridor plot

7. Surface wind trend forecast no change/change to ^{o}/ kt)



TOXIC CORRIDOR WORKSHEET

Name of Chemical ____________________

1. Source strength _________________lbs/min (from environmental health service, disaster response force, or estimated)

2. 54-6 foot delta-T __________°F (from instrument or table)

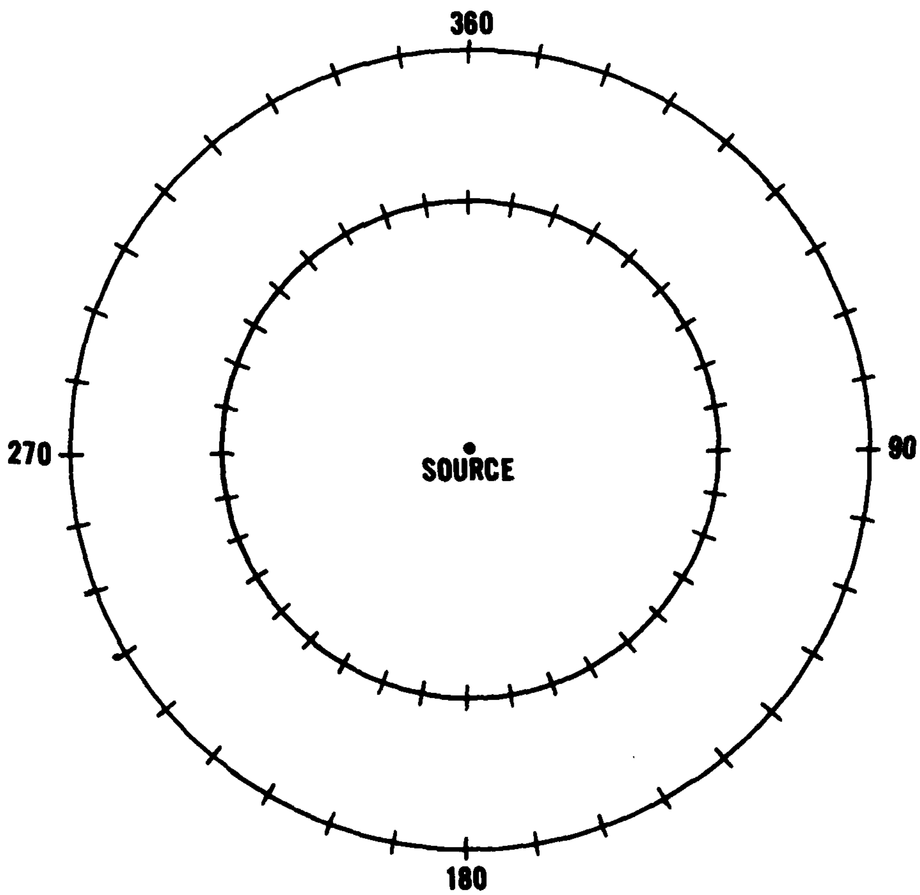
3. Toxic Corridor length ___________feet (from toxic corridor table)

4. Mean surface wind ____________________; wind variability (R) _____________ degrees (from wind trace, instrument dial, or estimated)

5. Corridor width (W) _________ degrees (W = 1.5R)

6. Toxic corridor plot

7. Surface wind trend forecast no change/change to °/ kt)



TOXIC CORRIDOR WORKSHEET

Name of Chemical ____________________

1. Source strength ________________lbs/min (from environmental health service, disaster response force, or estimated)

2. 54-6 foot delta-T _________ ^{o}F (from instrument or table)

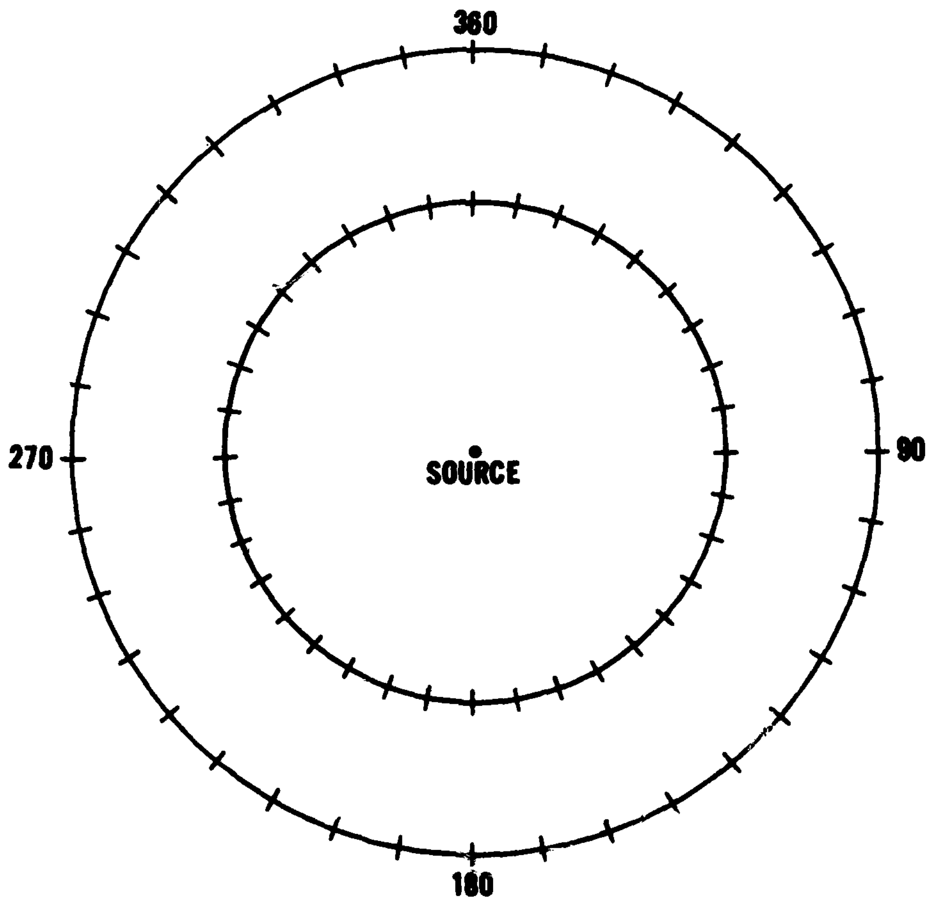
3. Toxic Corridor length __________feet (from toxic corridor table)

4. Mean surface wind ____________________; wind variability (R) _____________ degrees (from wind trace, instrument dial, or estimated)

5. Corridor width (W) ________ degrees (W = 1.5R)

6. Toxic corridor plot

7. Surface wind trend forecast no change/change to ^{o}/ kt)



TOXIC CORRIDOR WORKSHEET

Name of Chemical ____________________

1. Source strength ________________lbs/min (from environmental health service, disaster response force, or estimated)

2. 54-6 foot delta-T __________°F (from instrument or table)

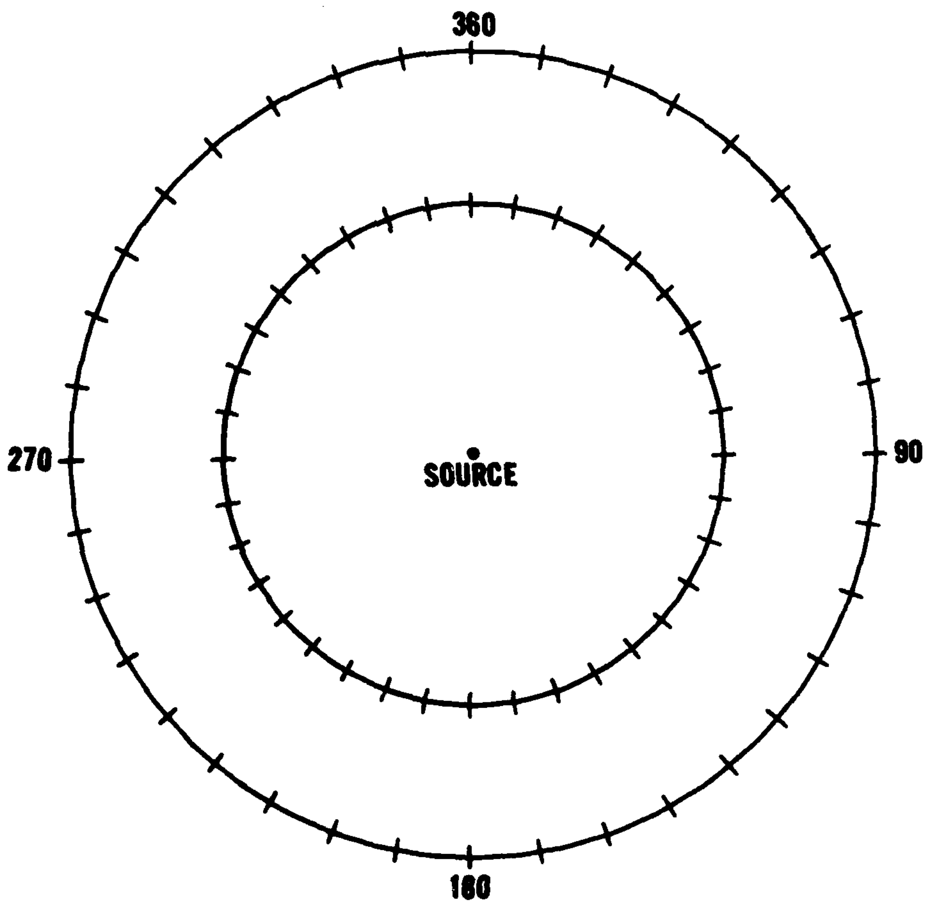
3. Toxic Corridor length ___________feet (from toxic corridor table)

4. Mean surface wind ____________________; wind variability (R) ____________ degrees (from wind trace, instrument dial, or estimated)

5. Corridor width (W) _________ degrees (W = 1.5R)

6. Toxic corridor plot

7. Surface wind trend forecast no change/change to °/ kt)



TOXIC CORRIDOR WORKSHEET

Name of Chemical ____________________

1. Source strength _________________lbs/min (from environmental health service, disaster response force, or estimated)

2. 54-6 foot delta-T __________^{o}F (from instrument or table)

3. Toxic Corridor length ___________feet (from toxic corridor table)

4. Mean surface wind ____________________; wind variability (R) _____________ degrees (from wind trace, instrument dial, or estimated)

5. Corridor width (W) _________ degrees (W = 1.5R)

6. Toxic corridor plot

7. Surface wind trend forecast no change/change to ^{o}/ kt)